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PREFACE.

A COURSE of lectures, delivered at Brighton by the late Dr. Mantell, on the Geology and Fossils of the South-east of England, formed the ground-work of the present work, so many editions of which have been favourably received by the public during the last twenty years.

The great advancement of geology and the collateral sciences, during the last ten years, has necessitated considerable modifications in several chapters of the present edition, so that the most important recent discoveries in palæontology, and the new or modified views of geological phenomena resulting from the progress of knowledge, might be incorporated in the respective Lectures.

The Editor has carefully adhered to the Author's praiseworthy plan of giving full references to the sources of published facts and opinions,—both for the sake of justice to previous observers, and to enable the student to work out for himself the subject-matter in hand.

If there be omissions in this respect, they will generally be supplied by the Author's "Medals of Creation,"

or other of his works frequently referred to, and containing the necessary references to special monographs and memoirs.

The "Medals of Creation," indeed, and the "Wonders of Geology" are intended to illustrate each other; the present volumes offering a familiar exposition of the *Philosophy of Geology*, and the "Medals" (2nd edition), a compendious view of the *Principles of Palæontology*.

London, Sept. 1857.

T. Rupert Jones.

OBITUARY NOTICE

OF THE LATE DR. G. A. MANTELL.

In preparing the present edition of the "Wonders of Geology," both the Editor and Publisher feel that it must be as agreeable to the reader to have some brief biographical sketch of the lamented Author, as it is grateful to their feelings to have an opportunity of connecting the well-earned eulogiums of his contemporaries with one of his favourite works.

The sympathies of Dr. Mantell's friends supplied several Biographical Sketches to the public journals, immediately after his decease; and at a meeting of the Clapham Athenæum was read a faithful and affecting notice * of his life and labours, as connected with Clapham,—one of the scenes of his untiring exertions to extend knowledge, and apply its advantages to his fellows.

"We have lost," says that sincere eulogist, "one of our earliest and staunchest friends, and science has lost one of her most pleasant, attractive, eloquent, and in-

* A Reminiscence of G. A. Mantell, Esq., LL. D., F.R.S., F.G.S., &c. Batten, Clapham, 1853.

structive advocates." Referring to this well-timed "Reminiscence" for much of interest, we extract from the Anniversary Address,* read in February, 1853, before the Geological Society of London, the following notice of our deceased friend, by the president, Mr. William Hopkins of Cambridge.

"On the list of those Fellows of our Society whose death during the past year we have to lament, stands first the distinguished name of

"Gideon Algernon Mantell, LL.D., member of many learned Societies at home and abroad,—who was a memorable instance of a man of genius, constantly and diligently occupied with the practice of a laborious profession, nevertheless reaching great eminence as a man of science, and finding time, even in the midst of pressing duties, to pursue his favourite studies with distinguished success. For several years he practised as a medical man at Lewes in Sussex, in a district which he has rendered classical by his researches into its geological structure. There he collected a vast number of interesting fossils, and formed a private museum, such as has rarely if ever been equalled. In the year 1835 he removed to Brighton, and four years afterwards from thence to Clapham, near London. At the time of his death he resided in Chester Square. When at Lewes, he published his principal separate works, "The Illustrations of the Geology of Sussex," and "The Fossils of the South Downs." The latter work, which was first in point of date (1822), appeared simultaneously with that of Cuvier and Brongniart upon the Geology of the

* Quart. Journ. Geol. Soc. vol. ix. p. xxii.

Environs of Paris, and many of the organic remains of the Chalk were described in both works simultaneously and independently. Whilst at Lewes he called attention to the interest and beauty of the remains of fishes found in the Chalk, and it was there that he commenced the series of observations which placed him in a prominent position among British geologists.

"The attention of Dr. Mantell was early directed to the phenomena exhibited by the strata of the Wealden formation. His most important discoveries sprang out of the researches which he never ceased to pursue amongst this his favourite group of rocks. At the time of his death he was occupied with the preparation of a work intended to embrace a general *resumé* of all that had been done about and among them at home and abroad. His location at an early period of his professional career was exceedingly favourable for these inquiries. He was assuredly the original demonstrator of the fresh-water origin of the mass of Wealden beds,—a great step in British geology. His observation of the conditions under which existing fresh-water shells and other bodies of fluviatile origin were imbedded in the alluvium of the valley of the Ouse, and even alternated with marine exuviæ, suggested the probability of the occurrence of similar, but infinitely more ancient, phenomena in the clays and sands of the Weald, and careful research fully confirmed his conjectures. With the Wealden, too, are connected his chief and very memorable palæontological discoveries. Out of that formation he procured the most interesting of the relics of prodigious extinct reptiles, which owe to him their scientific appellations, and whose remains will long constitute

some of the chief attractions of the great collection originally amassed by him, and now displayed in the galleries of the British Museum. Whether we regard his discovery and demonstration of the *Iguanodon* and its colossal allies in a geological point of view, as characterizing distinctly an epoch in time, or, with respect to their zoological value, as filling up great gaps in the series of Vertebrata and elucidating the organization of a lost order of reptiles, at once highest in its class and most wonderful, we must, as geologists and naturalists, feel that a large debt of gratitude is due to the indefatigable and enthusiastic man, out of whose labours this knowledge arose. In the group of Dinosaurian reptiles were some of the largest of terrestrial animals. In their organization, whilst truly reptilian, they approached the mammalian type. Their characters were so peculiar, that of the value and distinctness of their order there can be no question. Their osteology has been elaborated with skill and care, and has worthily occupied the attention of the most eminent anatomists. They gave a feature to the herpetology of the middle portion of the Secondary epoch. Now, of the five marked genera constituting this group, as at present known, we owe the discovery and demonstration of four, viz. *Iguanodon*, *Holæosaurus*, *Pelorosaurus*, and *Regnosaurus*, to Dr. Mantell. Worthily then was the Wollaston Medal and Fund adjudged to our lamented colleague in 1835, 'for his long-continued labours in the comparative anatomy of fossils; especially for the discovery of two genera of fossil reptiles, *Iguanodon* and *Holæosaurus*.' That he did not rest from his labours, after having received this honourable reward, the discovery of two additional

genera mentioned above can testify. Nor did he cease from continually seeking to perfect his knowledge of the wonderful animals brought to light during his earlier career. Thus, whilst the announcement of the *Iguanodon* dates as far back as 1825, his account of the jaw of this reptile was given to the world fifteen years afterwards. His paper on *Pelorosaurus* in the Philosophical Transactions was published in 1850. From the Royal Society he received the Royal Medal in 1849, as a just acknowledgment of his palæontological researches.

"Dr. Mantell was equally interested in all other branches of palæontology. One of his earliest papers was that concerning the bodies called by him and now well known as *Ventriculites*, found in the Chalk, and referred by him to *Alcyonia*. On Fossil Mollusca and Radiata he wrote many valuable papers, especially those that concern the *Belemnites* and their allies. He was the first to call attention to the preservation of traces of the animals of *Foraminifera* in chalk-flints, and he devoted much time to the investigation of these microscopic bodies. He was an expert microscopist, and possessed fine instruments (one especially presented to him as a testimonial of esteem when he resided at Clapham) and an extensive collection of preparations. He was also much interested in fossil botany, and published several papers on the remains of plants in the Wealden and Cretaceous formations.

"Among his most recent labours was the account of the remarkable reptile from the Old Red Sandstone, named by him *Telerpeton Elginense*, an animal of singular interest, since it must be regarded as the most ancient unquestionable relic of its class hitherto dis-

covered. At the time he died he was occupied with a description of a very singular fish from the Chalk, to which he intended to give the name of *Rhynchonichthys*.

"His labours were not confined to the fossils of his own country. He did much towards making known remarkable fossils from North America and from New Zealand,—countries in which his sons are worthily walking in the footsteps of their distinguished father.

"Dr. Mantell's influence in science did not, however, wholly, or perhaps chiefly, depend upon his original researches. As a popular expounder of geological facts, he was unequalled. As a lecturer, he had no rival;—fluent, clear, eloquent, and elegantly discursive, he riveted the attention of his audience, and invariably left them imbued with a love for the science he had taught them. His popular writings, of which 'The Wonders of Geology' and the 'Medals of Creation' are among the more useful, had a wide circulation, and are held in high esteem by general readers. The works just mentioned have a considerable reputation on the continent as well as in England, and have been translated into German. One of them, the 'Medals of Creation,' is almost the only book in the English language, in which a general survey of the extent of the fossil world, and an interesting outline of British palæontology, can be met with. No fewer than sixty-seven works and memoirs, of various degrees of length and importance, are enumerated in the 'Bibliographia Zoologiæ et Geologiæ' as having proceeded from his pen. These are all upon different subjects of geological or natural history interest; but besides these, he wrote not

a few antiquarian papers, and some professional disquisitions of value.

"For many years Dr. Mantell endured severe illness and excruciating bodily pain, owing to a spinal disease, the result of an accident. But no torture could destroy his love for science, and his energetic pursuit of geological research. Almost to the hour of his death he was actively occupied with scientific investigations. When once absorbed in an important inquiry, he spared neither expense nor pains in his pursuit after the truth, and, by his enthusiastic and glowing descriptions of his progress, excited all with whom he came in contact to assist in the work.

"Dr. Mantell died in his sixty-fourth year."

Another tribute of friendship and esteem was paid to the memory of Dr. Mantell by Prof. Silliman, of New Haven, Conn. U. S., whose lucid and comprehensive Introduction to the American edition of the "Wonders of Geology" is given in this volume. For many years correspondents, and of late mutually gratified by enjoying the pleasure of personal communion on the occasion of Prof. Silliman's presence in England, these distinguished geologists knew well how to appreciate each other's character; and thus does the survivor write * of his departed friend and of his works:—

"Gideon Algernon Mantell, LL.D., F.R.S., F.G.S., &c., died at his residence in Chester Square, London, November 10th, 1852, aged, we believe, about sixty-four.

* American Journal of Science and Arts, Second Series, vol. xv. p. 147.

"Often, during our editorial career of thirty-four years, have we been called to the painful duty of recording the death of men, coadjutors with us in the cause of science, and of not a few with whom we have been connected by ties of personal friendship; but never have we been so painfully surprised, as by the recent announcement of the sudden death of the eminent and excellent man named above.

"Thirty years ago, his splendid quarto of 320 pages, with 43 plates, devoted to the geology of Sussex, his native county in England, made its appearance. It was followed, at the end of five years, by a thinner quarto, equally a finished production, with 21 plates illustrative of the geology of the south-east of England, including Sussex and Tilgate Forest. These original works, abounding with interesting and instructive observations, established the author's reputation throughout Europe as an able geologist, and as an acute and successful expositor.

"The scene of his personal researches in geology, commencing at Lewes, his native town, extended from London and its vicinity to Brighton on the English Channel, and from Dover to the Isle of Portland, including Hampshire and the Isle of Wight, and never was a geological field more faithfully or more successfully explored. Dr. Mantell made also occasional excursions into Wales and Derbyshire, to Oxford, Edinburgh, &c. The fossils of the Chalk, and the colossal reptiles of the Wealden formation below the Chalk, make a conspicuous figure in his works, among a multitude of other organic relics of early creations.

"Dr. Mantell lived successively at Lewes, Brighton,

Clapham, and London, in all of which places he sustained an extensive professional practice, both in medicine and surgery, and still found time, in consequence of his great industry, to cultivate geology and the allied sciences, especially comparative anatomy, and to give many lectures on these subjects, in compliance with invitations from various towns and cities. As a lecturer, he was lucid, animated, and eloquent; and having the advantage of a noble presence, with a voice of great power and of a fine musical cadence, his appearance was eminently attractive. He had a perfect command of the most appropriate language, and his chastened enthusiasm always carried his audience along with him. His well-deserved celebrity insured on the part of the public a welcome reception to several important works, which, in the course of a few years, he wrote and published.

"The 'Wonders of Geology,' in two volumes, was an embodiment and enlargement of his lectures, and a more instructive and delightful work on that science has never been produced. It passed through several editions in England; and an American edition (printed in London) was published, prefaced by an introductory discourse intended to adapt the work more particularly to this country.

"The 'Medals of Creation,' also in two volumes, contained a learned and instructive synopsis of the fossils of all ages, and was illustrated by numerous excellent figures.

"The 'Geology of the Isle of Wight,' in one volume, gave a full and faithful account of that beautiful and remarkable island, replete with fossils, and containing

in its lower strata, limbs, vertebræ, and other bones of ancient reptiles, more colossal than any that had been before discovered. This work also is fully illustrated.

"Nearly the last of Dr. Mantell's great labours was a digested account of the fossils in the British Museum, with illustrations; it forms a thick volume, and is entitled 'Petrifactions and their Teachings.' It is a very interesting and instructive guide through the British Museum, and is fitted to be a pioneer in palæontology generally.

"Among his smaller works, the 'Thoughts on a Pebble' was a charming little book, adapted to the capacity of young people and even of children, while it was acceptable to the mature geologist; it passed through many editions.

"Two thin quartos, amply illustrated (as usual with the author), one on the Fossils of Sussex, and the other on the Geology of Leith Hill, are gems in geology.

"His 'Day's Ramble around Lewes' is an excellent guide in that region, both in geology and archæology. On archæology, as regards the proofs of the existence of man in different geological eras, he delivered an important lecture before the Archæological Society of Oxford University.

"To the list of Dr. Mantell's works, we add a handsome quarto narrative of the visit of William IV. and of Queen Adelaide to the ancient borough of Lewes, with original poetry and portraits. Also, 'Thoughts on Animalcules,' and a splendid Pictorial Atlas of Fossils, the illustrations chiefly selected from Parkinson's Organic Remains and Artis's Antediluvian Physiology.

"Of his numerous memoirs, those on the fossil rep-

tiles of the south-east of England—on the Belemnite and Belemnoteuthis—and on the Moa,* the extinct fossil bird of New Zealand, are among the most remarkable.

"Dr. Mantell, a number of years ago, sustained a severe injury on the spine, in consequence of a fall from his carriage, and an incurable tumour arose, which, by its pressure upon the nerves of the spinal chord, produced at first temporary paralysis, and subsequently, through life, frequent and intense neuralgic suffering, attended by great emaciation. Still his powerful and enthusiastic mind rose above his sufferings, although they often deprived him of sleep. He wrote several of his works while he was a martyr to pain; at the same time he continued his professional visits, and at the bedside of his patients, and when in society at home or abroad, he assumed a degree of cheerfulness which might have led any one to suppose that he was in perfect health. During the last week of his life he suffered intensely, and was deprived almost entirely of sleep; still, although observed to look unusually ill, he gave a public lecture, with his usual animation, two days before his exit, and visited his patients the very day before he died. He also continued to labour upon the new edition of the 'Medals,'† until he retired to his chamber, on the night preceding his decease. He was then in great suffering; and at 3 o'clock P.M., of November 10th, he passed gently away without a struggle, and probably was never conscious of his transition, until his spirit awoke in another world.

* "His eldest son, Mr. Walter Mantell, living in New Zealand, obtained and sent to his father a large collection of the bones of the Moa."

† Completed under the superintendence of Mr. Rupert Jones, and published by Mr. Bohn, in 1854.

"As a personal friend, Dr. Mantell was most interesting and estimable. His affections were warm, his intellectual perceptions acute, and his capacity for social enjoyment was so great, that the presence of a friend aroused his active mind even when suffering intense pain; his powers instantly rallied and poured forth treasures of knowledge, and often literary and poetical effusions with a natural eloquence and finished grace which made him a most delightful companion. In affairs of business, he was ever exact and responsible, and, as far as possible, left no pecuniary transactions to be finished by other hands.

"He was an elegant artist; his off-hand pen or pencil sketches, occasionally enclosed in letters to his friends, were both elegant and effective, and most of his illustrations in his earlier works were drawn by himself. It is stated on the title-page of the Geology of Sussex, that the drawings were made by the author, and the engravings were executed by Mrs. Mantell. This lady and three children survive.

"Dr. Mantell's ancestors were distinguished in several of the arbitrary reigns of England, as friends of human liberty, and some of them paid the price of their blood.

"Dr. Mantell was remarkable for his candour and kindness, and for scientific justice,* especially to ori-

* "Dr. Mantell transmitted to Baron Cuvier the then (1822) newly discovered teeth of the gigantic fossil reptile, since named the Iguanodon; and in the record of Cuvier's opinion, quoted by Dr. Mantell in his Geology of Sussex and Fossils of Tilgate Forest, 1827, p. 71, are the following expressions, which prove that he gave to the illustrious Cuvier the credit which was his due:—'Ces dents me sont certainement inconnus—je crois qu'elles appartiennent à l'ordre des reptiles: n'aurions-nous pas ici un animal nouveau, un reptile herbivore?'"

ginal discoverers, whether eminent or humble, and no British philosopher excelled him in liberality and courtesy towards the scientific and literary productions of this country and their authors.

"Although he sold to the British Museum, some years since, the greater part of his vast collection of fossils of the south-east of England, his private dwelling was still a rich museum of most interesting objects of nature and art :—everything conspired, in perfect unity, to one effect, corresponding with the accurate science and elegant taste of the lamented proprietor. The rare combination of exact and thorough scientific knowledge, with the enthusiasm of a discoverer, and the rich but chastened diction of a poet, were never more remarkably united than in him. His letters were a rich feast to his friends. Full of information and thought, and the kindest feelings, and being punctual in responding to letters addressed to him, those who were so happy as to enjoy his confidence and correspondence always hailed with joy his beautiful and well-known inscriptions.

"Dr. Mantell's early training in religion was under pious parents, and his retentive memory enabled him when young to repeat a large part of the Bible by heart. This statement, which came to us from his own lips, is in accordance with a fact which illustrates the power of his memory, that, in conversation, he would often repeat with perfect facility and accuracy, whole pages of his favourite English classics, and with that finished and graceful intonation for which he was so remarkable."

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ADDRESS TO THE READER.

GEOLOGY, beyond almost every other science, offers fields of research adapted to all capacities, and to every condition and circumstance in life in which we may be placed. For while some of its phenomena require the highest intellectual powers, and the greatest attainments in abstract science, for their successful investigation, many of its problems may be solved by the most ordinary intellect, and facts replete with the deepest interest may be gleaned by the most casual observer.

To the medical philosopher Geology presents peculiar attractions for those hours of leisure and relaxation, which are indispensable to maintain a healthy state of mind; for it requires the cultivation and application of Chemistry, Botany, Comparative Anatomy, Zoology, and Physiology,—sciences which form the very foundation of medical knowledge. It exerts, too, the most salutary influence, by calling forth the continual exercise of our intellectual powers; for the desire to explain what is obscure in the natural records of the past induces a more accurate examination of existing physical phenomena, and of the organization and habits of the living beings within the reach of actual observation. It enforces the necessity of weighing the conflicting evidence

of apparently irreconcilable phenomena, of detecting differences, and seeking analogies, and of generalizing and combining an immense number of isolated facts. The mind thus acquires the power of acute observation, of patient investigation, and of salutary caution in drawing inferences, and arriving at conclusions,—habits of the first importance in the discrimination and treatment of diseases.

And however little, in the present state of the public mind, such qualities may be appreciated, the labour will bring an ample reward in the self-conviction that the talents intrusted to us have not been given in vain.

> "Better than Fame is still the toil for Fame,
> The constant training for the glorious strife!"

For it should ever be borne in mind that the primary object of every study ought to be an inward one—that of enlarging and elevating the intellect; and the direct aim of science should be the discovery of the principles of unity, order, and connexion, which are everywhere manifest in the universal life of nature.

In proof that intellectual pursuits of the highest order are not incompatible with any situation in life, I would earnestly solicit attention to the following eloquent appeal by one of the most enlightened statesmen of our times :—

"Heed not the sneers and foolish sarcasms against learning, of those who are unwilling that you should rise above the level of their own contented ignorance. Do not for a moment imagine that you have not time for acquiring knowledge; it is only the idle man who wants time for everything. The industrious man knows the inestimable value of the economy of time, and amidst the most multifarious occupations, can find leisure for rational recreation and mental improvement. Do not believe that the acquisition of scientific knowledge will obstruct your worldly prosperity, or that it is incompatible with your worldly pursuits. Rely upon it, you cannot sharpen your intellectual faculties, you

cannot widen the range of your knowledge, without becoming more skilful and successful in the business or profession in which you are engaged." *

I may add, that by that happy connexion, whereby the useful is indissolubly linked with the true, the exalted, and the beautiful, science thus followed for its own sake will pour forth abundant overflowing streams to enrich and fertilize that industrial prosperity, which is the conquest of the intelligence of Man over matter.†

G. A. M.

* Inaugural Address at the opening of the Tamworth Institution, 1841, by the Right Hon. Sir Robert Peel, Bart.

† See Introduction to Cosmos, or a Sketch of a Physical Description of the Universe ; by Alexander Von Humboldt. (4 vols. Bohn, 1849-52.)

THE

WONDERS OF GEOLOGY.

INTRODUCTION TO THE AMERICAN EDITION,

BY

PROFESSOR SILLIMAN.

1. Object of the Science.—Geology is the natural history of the earth; its hills and mountains, its rivers, lakes, seas, and oceans, its fertile plains and sterile deserts—in a word, all that belongs to physical geography is comprised in this science. Incidentally, it takes notice of agriculture and commerce, of the various improvements of civilization, and of the races and families of animated beings of both organic kingdoms, since they are all influenced, more or less, by geological phenomena. Everything upon the globe is, therefore, connected with geology; which embraces likewise the principal physical facts and events of which our planet has been the theatre.

But the more immediate object of this science is to ascertain the structure of the earth, and the nature of the masses of which its crust is composed,—the order of their arrangement,—their mineral and organic contents,—the proximate causes by which they were formed and deposited, and those by which they are rendered liable to future changes.

2. Preliminary knowledge.—These considerations necessarily involve a knowledge of physical laws. We must be acquainted with the chemical constitution of matter, with the combinations its elements are capable of forming, with the liabilities of the com-

pounds to enter into new arrangements, and with the laws which govern these changes. The mechanical laws must also be kept in view; the weight, pressure, and moving power of solids and fluids, the varieties and force of attraction; in a word, the dynamics of our globe. Nor can the subject be considered entirely apart from the planetary relations of the earth, as a member of the solar system, and of the innumerable systems which compose the stellular universe.

Those subtle agents unknown in their essence, but most manifest and potent in their effects — namely, heat, light, electricity, and magnetism, either distinct, or combined in various modifications, demand also a faithful study, that we may comprehend their manifold and unceasing effects in the economy of the earth; nor must the enveloping ocean of aerial fluid, the atmosphere, in which their energy is so largely displayed, be forgotten; both in its physical and chemical characters, it demands earnest attention. We must also know the outlines of natural history, especially of the mineral species, or, at least, of those which are, or have been, chiefly concerned in producing, by their extension or aggregation, the mountains and continents, and the entire crust of our planet, so far as it is cognizable by man. Some competent knowledge of mineralogy ought, therefore, to precede the study of geology; it is true, we may begin with a comparatively small number of the most important minerals, as our increasing acquaintance with rocks will constantly augment our familiarity with the minerals which compose them.

In like manner, as mineralogy is indispensable to the study of geology, so the other departments of natural history are auxiliary to it in a most important degree. Animals and plants, either entire or dismembered, or in fragments, are contained in almost all kinds of rocks, except the primary * and the volcanic; nor can we assign the limit of organic matter even in these, for we know not how far fire, by softening or fusion, may have obliterated the organic remains that might once have been blended with materials now exhibiting no vestiges of plants or animals. Although we may not be able to mark the precise boundary beyond which organic beings do not appear, it is certain that in all geological epochs subsequent, at least, to that of the primary rocks, animals and plants have existed in successive families; they have been created, have lived their destined periods, and by the operation of physical causes have perished,

* The term "primary" in this Introduction refers to the metamorphic and granitic rocks.—Ed.

while new races have been called into being, and in their turn have ceased to be, in order to give room to other families, requiring, perhaps, new physical conditions.

Thus we travel onward in time, and upward in the order of deposition, through races whose species are entirely extinct, until we arrive at the periods that approximate to our own times, when similar beings to those that now inhabit the earth first begin to appear, and finally to graduate into those of the present day. Now it is obvious, that, to judge intelligently of extinct races of animals and vegetables, it is requisite to pass in review the entire organic creation, both of ancient and modern date; not only of the terrestrial animals that, in early times, walked the earth, of the fishes and amphibia that swam in the waters, of the birds, insects, and winged reptiles that soared in the air, and of the plants that adorned the new-born islands and emerging continents, and which, as well as the animals, are now entombed in rocks and mountains; but we must be familiar, also, with the races which, at this moment, fill the world with animation and beauty, for they are our living standards of comparison. In short, we must be well acquainted with both natural history and comparative anatomy.

If such be the circle of sciences preliminary or auxiliary to geology, it may well draw from us the desponding exclamation, Who then is sufficient for these things? We may perhaps reply, no unassisted individual. Science is formed by the joint labours of many minds. Different cultivators bring in the rich tribute of the fields they have tilled and reaped, and a master-mind disposes them in order, and draws from them the requisite conclusions to construct a system, or, at least, to furnish its most important elements.

3. Rank among the Sciences.—This very general sketch of the relations which geology sustains to the collateral sciences is sufficient to evince its high dignity, and to vindicate its strong claims to our serious attention. As a science, its date is modern; but this is also true of all the physical sciences, among which geology is a younger sister. Although it is rapidly advancing, and is, therefore, not perfect, but progressive, it is still a science; and, in this sense, which of the physical sciences is perfect? * In this

* "To boast of a stability of opinion in Geology, is to boast of an extreme indolence of mind; it is to remain stationary in the midst of those who go forward."—*Humboldt.*

respect geology is, therefore, not alone. Its ascertained facts are numerous; they are correctly observed and reported; they are skilfully classed, and a sufficient number of general as well as particular conclusions has been drawn from them to furnish the basis of a noble science. Its boundaries are daily extending, and will be extended without limit, by continued observations,—its evidence will constantly accumulate; and, although its theoretical speculations may change, nothing can occur to subvert the grand conclusion, that the earth has a regular structure, and that its materials have been arranged under the operation of general laws of great energy and duration, the physical expression of omniscient intelligence and omnipotent sway, guided by benevolent design, which becomes more and more apparent and convincing with every new and successful research in geology.

4. Sources of its evidence. — If the inquirer ask for the source of geological evidence, it may be answered that it is derived from diligent and careful examination of the structure of the earth; and for this object our means are more ample than might at first appear.

Every artificial excavation,—every well and cellar,—every cut for a fort, for a common road, a railway, or a canal,—every stone-quarry,—every tunnel through a mountain,—and every pit and gallery of a mine bored into the solid earth, furnish means of perusing its interior structure. Still more do the inland precipices, and the rocky promontories and headlands along the rivers, lakes, seas, and oceans; the naked mountain-sides ribbed with strata, that bound the defiles, gorges, and valleys; the ruins accumulated at the feet of lofty pinnacles and barriers, and those that have been transported and scattered far and wide over the earth, present us with striking features of the internal structure of our planet.

Most of all, do the inclined strata, pushing up their hard edges in varied succession, and thus faithfully disclosing the form and substance of the deep interior, as it exists many miles beneath the observer's feet.

Volcanic eruptions throw up into daylight the foundations of the fathomless deep below, in the form of ejected or molten masses, or in rivers of ignited and fluid rocks, which congeal on the surface of the ground, either inflated like the scoriæ of furnaces, or in solid masses, with no visible impress of heat; and often containing very perfect and beautiful minerals, elaborated in the volcano, or dis

lodged from still earlier beds. In addition to the products of actual volcanos — the ignigenous rocks, crystallized or deposited from fusion, both in the earliest and in many of the more modern epochs —injected among and traversing strata of all descriptions and ages, and thus assimilated to known products of internal fire, the proper rocky masses, the granites, syenites, porphyries, serpentines, and traps, give authentic information of the unapproachable gulf of fire whence they were projected.

The internal waters that gush cool from the fountains on the land or under the sea, or those that spout in boiling geysers from the deep caverns where their imprisoned vapours accumulate explosive force; all these bring to the surface the materials of the interior, and conspire with tornados of gas, bursting from volcanos and other vents, to reveal the deep secrets of the earth.

5. Its positive utility.—Geology, in addition to its adherent dignity, puts forth strong claims to regard on the ground of positive utility. Everything reposes upon the mineral kingdom; it affords to man, directly or indirectly, all the materials of his physical comfort,—all those of national wealth, and all the means of civilization. The most important of physical instruments are derived, immediately or remotely, from it; for the vegetable world, equally with the animal, rests upon this basis; whether we speak of the cedar, the oak, the lichens, or the grasses, all equally derive their support from the elements afforded by the mineral kingdom; which, in its widest sense, includes not only the solid earth, but its waters, and all its fluids,—its atmosphere and all its gases. The vegetable kingdom borrows not a few elements from the mineral world; oxygen, carbon, hydrogen, and even nitrogen, and all that are indispensable to vegetable life, are found in the waters or in the atmosphere; while other elements or compounds, adapted to particular purposes, are derived from various mineral sources; the soil, for example, affords silica, which enters into the composition of the epidermis of grasses, bamboos, equiseta, &c.; and potass and soda, derived from decomposed felspar and other minerals, pass by absorption into the juices of plants. Even animal and vegetable manures form no exception, for their elements have a similar origin, and consist almost entirely of the substances indispensable to vegetable growth.

Thus, while we explore this orb of gases, fluids, and solid rocks, we shall gain the most interesting knowledge, and much positive

advantage. Our beautiful planet is indeed worthy of our study; it was once our cradle—it will soon be our grave,—between the dawn and the night of life, it is the scene of our busy action, and from it we shall rise to another state of being.

6. Discovery of useful Minerals.—Geology discloses to us the valuable minerals, and teaches us where they are likely to be found, and where research would be vain.

Coal.—Coal is, without doubt, wholly of vegetable origin: hundreds of species of plants have been distinguished in the coal-formation, but none of these have been found living on the earth, although many of the families still exist; the recent allied species are generally of a diminutive size, in comparison with those of the coal-period, and those that approach the ancient in magnitude are chiefly found in tropical climates.

Duly informed in geology, we should never look for coal in granite,* nor among the most ancient rocks; and in the wide intervening series, a large part of the formations are excluded from the association with this most important mineral. Slates, shales, and limestones, charged with bitumen, afford indications of some value, but not decisive, as bitumen is associated with many minerals that do not belong to coal-formations. The impressions of plants in the rocks, especially those charged with bitumen, strengthen the presumption, and, should we find fragments of coal scattered in the soil, or mingled with gravel and sand in the banks and water-courses, or observe dark masses of earth, which, on close inspection, appear to contain fine coaly matter, we may infer that beds of this combustible may be near, and that it may be proper to dig or bore; and when, at last, we find the beds of coal, they will be regularly arranged between a roof and floor of coal-slate or shale. But it by no means follows, that beds of shale and slate necessarily indicate coal; those of the primary series would scarcely contain any combustible, unless it were plumbago, or possibly a little anthracite. The geological laws of coals are very strict, and a thorough acquaintance with them is the only safeguard against fruitless enterprises.

Lignite.—It is easy to mistake beds of lignite for coal: lignite, when found in sufficient abundance, is a valuable combustible, but it

* Coal-strata sometimes repose *upon* granite (not *in* it), as in France, and near Richmond, in Virginia.

is not perfect coal; it burns with a sharp and acrid odour like the smoke of a wood-fire, and is in fact wood only partially altered by inhumation. It is most abundant in the more recent geological formations, especially in tertiary sands, gravel, and clays, in which true coal has rarely been found. The trees that are buried in the recent alluvial and diluvial deposits are little altered, and are, for the greater part, referable to existing floras; sometimes they are flattened by pressure, and altered in their texture, and even partially carbonized.

Limestone and Marble.—Limestone, including chalk and marble, is a most useful substance. The ancient Grecian temples give decisive proof of the durability of marble; and its beauty, even after the lapse of two or three thousand years, and after innumerable aggressions by the violence of war, and the depredations of antiquaries, more destructive than the action of the elements, is in many instances not entirely destroyed. Limestone is the most important ingredient in mortar, and of great value in soils. But it is not necessary to enlarge on a subject so generally understood. It is sufficient to remark, that in the selection of limestone for architectural purposes, or as a fertilizing ingredient for soils, geological skill will often prove of great value; and in cases of high responsibility, such as the erection of public edifices, intended to endure to distant ages, the united services of the geologist, the stone-mason, and even the quarry-man, may well be put in requisition, for practical artists often acquire the skill to judge very correctly of the value of materials. The experience of all antiquity proves this to be true.

Various Rocks. — The same view may be taken of granite and syenite, and the schistose rocks of that family, of porphyries, traps, and soapstones, of sandstones and puddingstones or breccias. All these are employed either in constructing the external walls or in forming the interior decorations of buildings, as well as in forts, docks, bridges, quays, aqueducts, and roads; and it is of the utmost importance that time and expense should not be bestowed upon materials that are faulty or worthless: for some kinds of sandstones and limestones, and even granites, crumble away, upon exposure to the air and the weather, and thus produce deformity and dilapidation, where everything should be solid and enduring. In general, this error may be avoided by a careful observation of the effects of time and the weather upon such masses of rocks as chance to be prominent above

the ground, and have therefore been (perhaps for ages) subjected to those atmospherical agencies which the finished edifice must, in its turn, encounter.

Metals.—The researches for metals have ever interested mankind in a high degree, and on no subject are they more liable to error and imposition. Happily, the most important metal, iron, is the most abundant. But iron-ores are not always known by the uninstructed; some of the most valuable are not attracted by the magnet, until they have been heated in contact with carbon or hydrogen. Other ores are so completely disguised, that they are not recognised at all by those acquainted with the purified metals alone. This arises from their combination with various substances, chiefly oxygen, sulphur, acids, or arsenic, which, on account of the great change they produce in the properties of metals, are called mineralizers. Iron-pyrites, an abundant mineral of little value, is frequently mistaken for gold, because it is usually yellow; and this, notwithstanding it is hard and brittle, while gold is soft and malleable, so that a mere blow of a hammer would detect the difference. Yellow mica has been gathered for gold-dust; and silvery mica and white arsenical iron have been mistaken for silver.

Calamine, the native oxide of zinc, has no resemblance to any metal whatever; and *tin-stone*, the native oxide of tin, has none to that metal; and both would be rejected by an ignorant observer. The same may be said of the sulphuret of silver, the gray sulphuret of copper, the chromate, molybdate, carbonate, phosphate, and sulphates of lead, and many more. Few persons, indeed, trust themselves to carry on great works in mining without previously consulting professional men; some are, however, so perverse, or blinded, as to persist even against the best counsels, and they, of course, pay the penalty of their folly in disappointment, and oftentimes in utter ruin.

Geological Associations of Metals.—It is well known to geologists, that metallic veins are rarely found in the most recent formations; and, with the exception of iron, and of alluvial deposits of other metals, they seldom occur in great abundance, until, in the descending series, we approach or pass the geological epoch of coal. In the transition-rocks, certain metals abound, while others occur in the primary, and there is no rock so old that it may not contain some of the metals. Sound scientific views of the geological structure of a country will therefore serve as an important guide in the research

for metals, and in forming a conclusion as to the probable continuance, enlargement, or cessation of metallic veins.

Decisions of Science.—The negative which science often pronounces with entire confidence may save many an excited mind from delusion, and preserve for agriculture and the useful arts of life the resources which might have been lavished, in reckless profusion, upon vain and unproductive mining operations. It is rarely that metallic mines will justify the abandonment of a useful calling in the common walks of life; even where there is abundance of valuable ore, few individuals can, alone, afford to encounter the enormous expense of mining, and to wait its uncertain and, it may be, distant and stinted returns. A good quarry of soapstone, granite, gypsum, or sandstone may be worth more than a mine of gold, and such have actually been the opposite results in some signal cases in this country. To these few instances of the importance of geological knowledge to the common interests of life, many more might be added, but these are sufficient to illustrate our argument; if, indeed, it be necessary to prove, that he who acts with consummate knowledge proceeds with safety, walking in the full and certain light of science, while he who adventures in the dark has no right to expect anything but disaster and ruin.

Geological Surveys by Public Authority.—That there is a just appreciation of this subject among the people of this country is sufficiently evinced by the geological surveys of many States and Territories, either already accomplished or in progress. More than one-half of the States have, by public authority, instituted such surveys; the reports which have been published evince industry, knowledge, and skill: great progress has been made in developing the mineral resources of the country, and in amassing stores of materials to serve for a future digested and systematical account, both scientific and practical, of North American geology;* while, at the same time, excellent schools are thus established, in which to form young geologists by actual and responsible explorations and surveys. These good works will, we trust, proceed, until our whole territory has been geologically examined, when some gifted individual will give us the grand result. In a scientific relation, these researches are deeply interesting, and we are in this way, as well as by personal efforts, contributing our share of materials towards the general stock of geological knowledge.

* See Special Report on the New York Exhibition, by Lyell and Hall, 1854.—Ed.

7. Some features in North American Geology.—Perhaps no country is more favoured than our own, in the nature, abundance, variety, and distribution of the most important mineral treasures. The limits of these preliminary remarks can only present the most general summary of our geological formations, or at most admit of nothing more than a mere sketch; but the materials for information are already abundant, and are yearly increasing, as may be seen in the various public reports, in the transactions of our learned societies, and in our journals of science.

Of the primary and transition rocks, to which we may add the coal-formation and the silurian, we have immense ranges, extending in a north-easterly and south-westerly direction through the continent, and comprising most of the minerals, and many of the fossils, that are found associated with such groups in the old world.

Alleghanies.—The Alleghanies (including many mountains having local names), following the general bearing of N.E. and S.W., and ranging between the Mississippi and the Atlantic, form, with their branches and connected chains, the great rain-shed of the countries east and west; and, rising to two, three, four, and five thousand feet and more,* give direction to the streams and rivers, that flow either into the Mississippi, the Atlantic, or the great lakes and the St. Lawrence.

Rocky Mountains.—In like manner, the far more stupendous chains of the Rocky Mountains, whose loftiest peaks are reported to be between three and five miles high,† give a geological character to the regions east and west, in which directions the waters flow to the Mississippi and the Pacific, while other contributions descend to the Gulf of Mexico, and to the Northern Ocean. It is to be regretted, that in the United States proper there are no mountain-ridges, or solitary peaks, that pierce the regions of perpetual cold.

Mount Washington.—Mount Washington, of the White Mountain group in New Hampshire, which approaches a mile and a quarter in height, being in 44° of north latitude, on a continent whose average temperature is many degrees below that of Europe, throws off its snowy mantle only for a short season, in July and August,

* Professor Mitchell, University of Chapel Hill, states that the top of Black Mountain, in North Carolina, is 6476 feet above the level of the ocean. See Am. Journal, vol. xxxv., No 2.

† See Professor Renwick's Outlines of Geology.

while it is clad in white during the remaining months of the year. Even on the first day of September (1837), as adventurers upon this Alpine mountain,* we were, both on its flanks and summit, involved in a wintry tempest of congealed vapour, formed into splendid groups of feathery and branching crystals, unlike to the snows of the lower regions: the driving masses came in fitful gusts, veiling in a white cloud all objects far and near; but breaking occasionally to admit a flood of solar light, and render visible this hoary pinnacle and the deep gorges and valleys of the neighbouring groups of mountains.

The mountains of Essex County, State of New York, between Lake Champlain and the St. Lawrence, approach the White Mountains in altitude, but none are permanently snow-clad.

Mountains of Central Europe.—It is otherwise in Europe, where the grand central group of Mont Blanc, and the various Alpine mountains, rise far into the region of perpetual congelation; and Mont Blanc would pierce that region even at the equator. Thus is provided an eternal storehouse of ice and snow, over whose wintry surface the winds, rendered heavier by contact, glide into the valleys and plains of the countries at their feet, and thus temper even the warm climate of Italy, preventing the extreme vicissitudes which we experience.

But these immense natural magazines have a still more important relation to the irrigation of the vicinal countries. The melting of the snow and ice, by the heat of summer, supplies copious streams to feed the innumerable rivers that flow from these grand fountains, to almost every part of continental Europe, south of the Baltic. Thus the effects of drought are, in a great measure, prevented, while destructive mountain-floods are of rare occurrence.

From the absence of such mountains we have no permanent stores of ice and snow, and, consequently, our rivers are liable to extreme variations of altitude and force. The Ohio, in midsummer, sometimes leaves numerous fleets aground, while occasional risings, from deluging rains, swell the river to an immense flood, that spurns the barrier of the banks, inundates villages and cities, and, expanding into an internal sea, rushes with wasting violence over the widespread meadows and farms. For this reason, hydraulic engineering is in this country attended with peculiar difficulties, both on ac-

* See Am. Jour. Science, vol. xxxiv. p. 74.

count of a deficiency and an excess of water; the former rendering the works inoperative, and the latter invading or sweeping them away.

The future civilized inhabitants of the countries near the Rocky Mountains (excepting, of course, the immense sandy deserts, which, near the eastern slope, emulate the sterility of Arabia and Zahara) will enjoy advantages in many respects similar to those of Piedmont, Switzerland, Germany, and France; and it is easy to predict, that peculiar structures, and a peculiar state of society, will be modelled upon the sublime physical features of those truly Alpine regions. From this, his native land, we have too much reason to expect, that, despite of the efforts of the benevolent to avert the impending doom, the red man of the forest, not reclaimed to humanity, but abandoned to his fate, will vanish before the knowledge and power, and the still more prevailing seductions, of civilized life,—the exterminated victim of cupidity and cruelty.

Influence of Geological Structure on Society.—It is perfectly apparent to geologists, that the scenery of a country is not more exactly stamped by its geological formations than are the manners and employments of its inhabitants.

New England.—Thus the bleak hills and long winters of New England being unfavourable to the most extensive and profitable agricultural pursuits, while the extensive and deeply indented sea-coasts, abounding in harbours, headlands, rivers, and inlets, naturally produce an impulse towards the ocean, conspire with the original adventurous character of the population, to send them roving from the arctic to the antarctic circle, till the wide world is laid under contribution by their enterprise. The numerous streams and water-falls furnish the cheapest means for moving machinery, and thus manufactories spring up, wherever, in the expressive phraseology of the inhabitants, there is *water-power*, and steam supplies local deficiencies of moving force. Ingenuity, conspiring with a general system of education, is excited, under such culture, to produce numerous inventions; and hosts of young men seek their fortunes successfully abroad as mechanics, seamen, traders, instructors, and politicians, and thus operate powerfully and, we trust, beneficially, on other communities.

Southern States.—The immense tracts of rich alluvium in the southern States,—the mildness of the climate,—the coasts less abounding with safe inlets, and often modified by the action of the

existing ocean, with a population not originally commercial, give a decided impulse to a vast agriculture, and a few great staples form the chief reliance of the landholders. It is easy to see, that this state of things grows out of the newer secondary, the tertiary, and the alluvial formations, which constitute the ocean-barrier from Staten Island to Florida, and from Florida to Texas, extending inland toward the mountains.

Western States.—In the west, the boundless fertile prairies and other tracts of productive soil conspire with remoteness from the ocean to indicate agriculture and pasturage as the main employment of the inhabitants; while exhaustless beds of coal, limestone, gypsum, and iron, and rich veins of lead and copper, and numerous and copious salt-fountains, furnish means for a manufacturing as well as an agricultural population. These pursuits occupy the greater number of the people, while many find a profitable employment in navigating those immense inland seas, the great lakes, and the vast rivers, which run thousands of miles before they mingle with the ocean. This state of things is the result of the immense extent of the lower secondary and transition formations which cover the western States, sustaining portions of tertiary strata and alluvial deposits.

While New England produces granite, marble, and other building-materials of excellent quality, Pennsylvania, with the western and several of the southern and south-western States, supplies inexhaustible magazines of coal, which prompt and sustain the manufacturing interests of this wide country, and aid its astonishing navigation by steam, already of unexampled extent on its internal waters, and destined at no distant day to compete, on the main ocean, in amicable rivalry, with our parent country.

Geological Treasures.—Our coal-formations, in richness and extent, are unrivalled in the whole world; our iron and lead are in the greatest abundance and excellence; Missouri has mountains of pure oxide of iron, that have no compeers, and there is a fair prospect that copper will also be found to abound in the West. We have great deposits of limestone and marble, of gypsum, marl, and salt, and of building-stones of almost every kind; our soils are so various in quality, and in geographical position, that almost every agricultural production is obtained in abundance. It is obvious, then, that we have all the physical elements of national and individual prosperity, and that the blame will be our own, if we do not follow them up by

proper moral and intellectual culture, which alone can render them sources of public and private happiness.

Geological Deficiencies.—Upper Secondary.—Of the upper secondary, below the chalk and above the new red sandstone, lying higher than the coal, we have no well-ascertained strata; rocks of oolitic structure we may have, but it is not ascertained that we have the true Oolite of England and continental Europe, nor have we traced the Wealden nor the Lias * with their colossal animal wonders.†

Equivalent of Chalk.—Chalk, properly speaking, appears to be absent from the United States; but there is an equivalent to the chalk-formation in vast beds of sands and marls, containing many European cretaceous fossils, between the Delaware river and the shores of New Jersey, as well as in various places in the south.‡

Absence of Volcanos.—The principal deficiencies in the geological formations of the United States are in the absence of active volcanos, and of most of the members of the upper secondary. However interesting active volcanos, with their earthquakes and eruptions, may be to speculative geologists, the sober unscientific population of our States may well rest contented without them, satisfied to barter the sublime and terrific for quiet and safety. Although the soils formed from decomposed lava are often fertile, and the vine flourishes luxuriantly on the flanks and at the feet of the volcanic mountains of warm countries, these influences are too local to be of much importance to agriculture.

Within the United States proper, including the states and territories beyond the Mississippi and east of the Alleghany Mountains, there is not, so far as we know, a single active volcano, nor even an unequivocal crater of one that is dormant. It remains yet to be decided, whether in and beyond the Rocky Mountains, quite to the shores of the Pacific Ocean, there are any active volcanos within our parallels of latitude. Both north and south of our limits, there are, on the islands and shores of the Pacific, numerous volcanos, and it would be strange, indeed, if there were none within our extensive possessions on the same coast.

Records of volcanic action in the far West.—However this may be,

* It is plain that the Lias, so called, in the West, is not like the Lias of England.

† M. Jules Marcou and others have lately pointed out that jurassic fossils have been met with, though to a very limited extent, in Virginia, the Rocky Mountains, Katmai Bay (N. W. coast), and in Chili.—EDIT.

‡ See Dr. Morton's Synopsis of the Organic Remains of the Cretaceous Group of the United States, 1 vol. 8vo, with plates; 1842.

there remains no doubt that fire has done its work, on a great scale, among the Rocky Mountains, and between them and the Pacific; for all our travellers attest the existence of immense regions covered with scoriæ and other decidedly igneous products, as if there had been actual and vast eruptions, within a period too short for decomposition to have reduced those tumefied and semi-vitrified masses into soil.

Trap and Basalt.—Regular formations of trap, and of basalt with symmetrical columns, are common among and beyond the Rocky Mountains, and the rocks of this igneous family are frequent in many parts of the old United States. They abound in New England, New Jersey, and the Carolinas; and, as usual elsewhere, they protrude their dykes among the rocks. In New England, and especially in New Hampshire, they often divide the primary rocks, cutting even granite-mountains from top to bottom; branching out, in many places, with numerous veins either dying away to extinction, or, perchance, returning again to the main current after having cut off a portion of the invaded rock. The White Mountains of New Hampshire abound in such phenomena.

Similar intrusions are found in the mountains of Essex, Lake Champlain, New York, and in many other places, and the primary rocks on the coasts of Massachusetts and Maine, as well as in the interior, are wonderfully cut up by invading veins and dykes of trap, basalt, and porphyry, and even of granite itself. It appears, also, that in the State of New York, limestone and other rocks, including the primary, and not excepting granite, are traversed by intrusive trap.*

Tertiary Formations.—Our tertiary formations are exceedingly extensive, and are rich in fossil remains. They bound a large portion of the sea-coasts south of New England, quite to the Mexican gulf, and up the Mississippi and Missouri: these oceanic deposits are also found, extending hundreds of miles into the interior from the coasts, where, as well as near the sea, they furnish, in their calcareous marls, inexhaustible resources for agriculture. Even on the shores of New England, there are marine tertiary deposits, as at Gay Head, in Martha's Vineyard, and elsewhere in that vicinity; while there are, in every part of the United States, innumerable inland deposits of fresh-water tertiary.

Boulders. — In boulders and rocks of transport our country

* See Professor Hall, in the Geological Reports for 1838; [and in Sir C. Lyell's Special Report on the New York Exhibition, 1854.—Ed.]

abounds; vast regions of older secondary and transition strata are occupied, more or less, by ruins of primary rocks, some of them of vast size, while the primary countries themselves, and the transition too, are marked by their own *disjecta membra*. We are precluded by our limits from discussing the causes of their transportation, whether by floods, ice-floes, or other motive powers. It is almost unnecessary to remark, that pebbles, gravel, and sand are found, as in other countries, transported and distributed, without doubt, by the action of water.

8. Beauty and interest of Geology as a Science.—In relation to the beauty and interest of geology as a science, we can hardly trust ourselves to write, since, within our prescribed limits, we have no room, and there is little occasion to describe that which our Author has, everywhere, treated with signal ability and eloquence. It may, however, serve to engage the attention of those to whom geology is a *terra incognita*, if we, in this place, remark, that no field of science presents more gratifying, astonishing, and (but for the evidence) incredible results. It teaches us that man has been but a few thousand years a tenant of this world; for nothing which we discover in the structure of the earth would lead us to infer that he existed at a period more remote than that assigned to him by the Scriptures. Had he been contemporary with the animals and plants of the early geological periods, we should have found his remains and his works entombed along with them.

This argument forcibly impressed the mind of Bishop Berkeley a century ago, and the following beautiful passage is cited from him by Sir C. Lyell: *—"To any one who considers that, on digging into the earth, such quantities of shells, and in some places bones and horns of animals, are found sound and entire, after having lain there, in all probability, some thousands of years, it would seem probable that gems, medals, and implements in metal or stone might have lasted entire, buried under ground forty or fifty thousand years, if the world had been so old. How comes it then to pass that no remains are found, no antiquities of those numerous ages preceding the Scripture accounts of time; that no fragments of buildings, no public monuments, no intaglios, cameos, statues, basso-relievos, medals, inscriptions, utensils, or artificial works of any kind, are ever discovered, which may bear testimony to the existence

* Principles, 5th Ed., vol. iii. p. 255.

of those mighty empires, those successions of monarchs, heroes, and demi-gods for so many thousand years? Let us look forward for ten or twenty thousand years to come, during which time we will suppose that plagues, famine, wars, and *earthquakes* shall have made great havoc in the world, is it not highly probable, that at the end of such a period, pillars, vases, and statues, now in being, of granite, or porphyry, or jasper (stones of such hardness as we know them to have lasted two thousand years above ground without any considerable alteration), would bear record of these and past ages? Or that some of our current coins might then be dug up, or old walls and the foundations of buildings show themselves, as well as the shells and stones of *the primeval world*, which are preserved down to our times." * This remarkable passage proves that the great man from whom it fell saw the geological argument in a true light, and felt its force to such a degree as to convince him of the great antiquity of the earth, which he justly viewed, as in no way inconsistent with the comparatively recent origin of man, or with the historical account of both events contained in the Genesis. It is easy to understand how such a mind would have been convinced, warmed, and excited even to enthusiasm by the discoveries that have burst upon us during the last fifty years.

9. Organic Remains.—As we descend from the alluvial soil under our feet, through the strata, the lowest of which lies upon the granite or the early slates, we are seldom without the records of life, in ages long past, and those records are drawn both from the animal and vegetable world.

Early Animals. — Shells of molluscous and testaceous animals are everywhere seen; their forms, their casts, their substance, are apparently preserved in stone, but generally converted, by the substitution of mineral matter, into true fossils. Myriads on myriads of these things are found, not merely in the superficial strata, but in the heart of the mountains, and at profound depths, forming an essential part of the solid framework of the globe.† The animals and plants are not accidental resemblances, but authentic specimens of ancient organisms, enclosed in the strata and mountains, as the materials, in mechanical or chemical suspension in the waters, concreted around them.

* Alciphron, or the Minute Philosopher, vol. ii. pp. 84, 85. 1732.

† See the list of strata formed wholly, or in great part, of organic remains, in our Author's Eighth Lecture; and in his "*Medals of Creation.*"

Fossil Fishes. — If we descend from the strata of newest formation to those that lie near or upon the primary rocks, we find not only that crustaceous and molluscous animals, of various kinds, have existed in the early periods, but that fishes have occupied the waters of almost all geological ages since life began, and that among the earliest, even those that are buried beneath the coal, there were races of great size, power, and ferocity; formidable from their teeth and jaws, which had, in some species, a structure like those of reptiles; and they had forked tails with unequal flukes, which enabled them quickly to turn over on their backs before striking their prey. The fossil fishes of particular genera and species are characteristic of particular geological formations—they extend geographically, far and wide, to distant countries, so that certain species may, if found at all, be expected in similar rocks in Europe, in America, in Asia, and Africa; and they are of every size, from inches, and fractions of an inch, to several feet. They occur either solitary, or in groups, or in fragments, or in immense shoals, like those of Monte Bolca, near Verona, in Italy, where there are several hundred species; still, scarcely a single fish of the strata that precede the most recent tertiary is identical in species with any now existing in the waters of the globe.

Fossil Vegetables.—Vegetables are found in strata of nearly all geological ages, and the labours of Count Sternberg, of M. Adolphe Brongniart, and of many other able botanists, have proved that a peculiar vegetation, adapted to the temperature, the degree of moisture, and other circumstances of the earth's successive surfaces, attended the different geological epochs.

Splendid and expensive works are now in the hands of geologists, containing exact delineations of the fossil vegetables, as far as they have been ascertained. These fossil plants are of all dimensions, from minute confervæ and lichens to gigantic trees; their structure, from mere fragments to perfect plants, has been beautifully delineated; roots, trunks, branches, and leaves, with the most delicate ramifications of the skeletons of the latter, have been examined; and in some rare cases, the more perishable organic fructification has been made out, and the fruits themselves have been identified.*

* See our Author's work, entitled "*Medals of Creation*," for a lucid summary of the fossil remains of animals and plants at present known.

Vegetation of the Coal-period. — The most exuberant vegetation appears to have been that of the coal-period, and its entombed treasures now supply the world with fuel, especially in countries where the forests are exhausted, or where economy of the modern vegetation, or preference for the results of the ancient, decides the choice.

Varieties of the Ancient Fossil Vegetation.—The ancient vegetation appears in many forms, as in that of lignite, of coal, and of siliceous, calcareous, and ferruginous petrifactions, still preserving the peculiar structure; and this has been made still more distinct and satisfactory, by cutting thin slices of the petrified trunks, and grinding them down until they become transparent, when the microscope reveals the internal structure which characterizes the family. Thus, it has been made to appear, that coniferous trees of forest-growth occur in the coal-formation in the south of Scotland and the north of England; and that zamias and other palm-like trees were coeval with the chalk in the south of England. But no species of the ancient world are identical with any of the modern, and the early vegetation implies, generally, a warm and moist climate and great fertility of production.

Aquatic Animals. — Reptiles. — The abundance of remains of animals, almost exclusively of marine species, attests the great prevalence of the ocean in the earlier geological periods, and it is not until we have passed the coal in the ascending order, that we begin to find reptiles of marine or of amphibious families, and ultimately, still higher up, of terrestrial races. With a similarity of type to the families of the present day, both the genera and species are, however, with but very few exceptions, extinct. Some were carnivorous, and swam in the shallow seas, estuaries, lagoons, and bays, and preyed upon fishes, molluscous animals, and each other; some lived on land and were herbivorous; a few genera, the megalosaurus and iguanodon, for example, were colossal in size and terrible in form, but it is probable that the latter of these terrestrial saurians was harmless and inoffensive, while the tooth of the megalosaurus would indicate a carnivorous animal, like the marine saurians. Bones of many genera and species of the reptile tribes, especially the saurians, have been found, and of some individuals, entire, or nearly perfect skeletons;—among them, several of vast dimensions have been discovered enclosed in the solid rocks,

along with their petrified and half-digested food, and with their coprolites.

Marsupials.—If the reptiles formed the transition from the marine animals upward, the marsupials, as they are called, were the link between the ancient reptiles and terrestrial quadrupeds. The marsupials, of which the opossum is an example, receive their young (which, when born, are still immature) into an exterior pouch or abdominal sack, and there nourish them at their paps, until they are fitted to go abroad, and to encounter the vicissitudes of their peculiar modes of life. These are the only animals hitherto found below the chalk which approximate to the proper terrestrial character. Dr. Mantell has, however, found the bones of birds in the Wealden beneath the chalk, and our own countrymen, Professor Hitchcock and Dr. James Deane, have discovered numerous tracts of bipeds, probably of birds, some of them of gigantic dimensions, in the new red sandstone of the Connecticut river.

Fossils of the Chalk and Tertiary.—The chalk then follows, with its immense and varied marine treasures,—fuci, corals, echinoderms, mollusks, fish, reptiles, with drifted wood, &c.: and then the lower tertiary, still marine: and next, the middle tertiary, where proper and fully characterized terrestrial animals are first found in abundance. Through the remaining beds of tertiary, both marine and fresh-water, we find molluscous animals, fishes, reptiles, and vegetables, verging towards, and many identical with, those of our own times; and occasionally we discover also terrestrial animals, but mostly different from the modern; until, at last, in the diluvium and alluvium, and the most recent sedimentary and concretionary formations, we discern animals and plants, still more and more like those now living, and finally graduating into perfect identity with existing races.

No Fossil Remains of Man.—Man and his works appear only in the last stages, associated with such beings as now exist, both in the animal and vegetable world. The pages of our Author will disclose the great variety and extraordinary forms, and, in many cases, colossal dimensions, unrivalled at the present time, of some of the ancient animals, the megatherium, the sivatherium, the dinotherium, the mastodon, the elephant, the hippopotamus, the rhinoceros, the cavern bear, the tiger, and many others. But in consequence of the most recent discoverics of geology, we are

hurried from that which is stupendous and vast, to that which is inconceivably minute. The extremes of creation meet in the mineral kingdom. In the solid rocks are found both the colossal reptiles and the microscopic infusoria. Ehrenberg has discovered that polishing slate is made up of the cases or shells of infusoria so minute, that forty-one thousand millions of them are required to fill a cubic inch, and these siliceous shields are the cause of the well-known effect of the tripoli, or rotten stone, in polishing steel, &c. An analogous constitution has been discovered in certain flint, opal, and bog-iron; and extensive deposits of marl, &c., in this country, are composed of similar remains, figures of many of which have been given by Professor Bailey, in the American Journal of Science. Even the soft parts of the foraminifera have been detected in the chalk and flint of England by our Author.*

10. General Remarks.—Such is a very general and imperfect sketch of the progressive groups of animals and plants that have inhabited our world, have become extinct, and are, in countless myriads, entombed in the strata and in the solid rocks. It is only on the upper surface that we discover loose and scattered boulders and fragments of rocks, and beds of gravel, sand, and detritus, the ruins of more ancient strata; in short, such accumulations of drifted and alluvial materials as we could with reason attribute to catastrophes of rising and rushing water, the deluges of geologists, or the deluge of the Scriptures; the latter, almost alone, being admitted to the contemplations of those who are uninstructed in our science. Now, it is a matter of physical demonstration, that the earth existed for many ages before Man was created; the whole course of geological investigation proves this view to be the only one that is consistent with the facts. To be convinced of its truth, it is only necessary to become thoroughly acquainted with the innumerable records of a progressive creation and destruction which the earth contains, inscribed on medals, more replete with historical truth, and more worthy of confidence, than those that have been formed by man; as much more as nature exceeds in veracity the erring or mendacious records of the human race.

11. Consistency of Geology with the Scripture History.—Hardly two centuries have passed since the astronomical doctrines

* See Philosophical Transactions, for 1846.

of Galileo, Kepler, and Newton were regarded as inconsistent with the Scriptures, and therefore heretical; but, although the discrepancy of the literal meaning of the Bible with the real truths of astronomy is still as great as ever, no one any longer hesitates to regard astronomy as giving a just view of the stupendous mechanism of the Universe;—all agree in understanding the language of the Scriptures as being adapted to the *appearances* of the heavens, of which alone mankind in general can form any just conception, and with which alone the Scriptures are concerned. The Bible, being designed as a code of moral instruction, as a revelation of a future life, and of the sanctions that belong to that momentous subject, contains no systems of philosophy. Moral science, essentially contained in the Scriptures, is not, even there, presented in a regular form, as in human systems, but in modes more happily adapted to the actual condition and capabilities of mankind.

In relation to physics, the information contained in the Bible is only incidental. God is declared to be the Creator of the heavens and the earth,—the physical universe,—and throughout the sacred volume there are innumerable allusions to, and illustrations of, his character, as its Creator and Governor: but there is not even the most general outline of any physical science. The creation of the heavens and the earth, of the sun and the moon, are disposed of with extreme brevity, while the allusions to the geological arrangements of this planet are only such as are connected with the first appearance of its organized beings, and the emergence of the land from the original ocean.

Instruction in the sciences was not the object of the Scriptures; the physical creation was left by its Divine Author for the delightful exercise of our faculties, and to afford an inexhaustible source of mental and moral pleasure;—for application to use, to increase the power and the comforts of man—an equally unfailing fund of improvement, and for the additional illustration of the character of God; an exhaustless fountain of knowledge, mingling its streams harmoniously with those of divine revelation.

From the study of the physical creation, Man has, therefore, drawn all the natural sciences, of which Astronomy is the most sublime and splendid, while Geology yields, in this respect, only to astronomy. Neither astronomy nor geology is, however, enunciated in the Scriptures, but both are revealed in the book of Nature, and

the astonishing truths which they unfold have been brought to light by human research.

While, as already remarked, the science of astronomy is, in fact, inconsistent with the *apparent* movements in the heavens, and, therefore, with the literal and popular phraseology of the Scriptures, which allude to physical things as they appear to the uninstructed mind, and not as they are in reality,—geology presents not even this discrepancy, but, on the contrary, a substantial agreement in its facts with the Scriptures. The latter describe a physical creation of mineral matter, and a successive creation of plants and animals, ending with man; while geology, by irrefragable demonstrations, which nothing but a study of the earth could afford, proves this history to be true.

The Scriptures describe a universal deluge; and geology shows that every part of the earth is marked by the effect of such visitations, occurring at one time, or at many times;—a repetition of local deluges, or a general one, would produce similar results; and although it may be impossible to distinguish between the accumulated effects of local overflows, and a general diluvial devastation, the surface of the earth is everywhere strewn with diluvial debris. The Scriptures declare that there was a beginning, and geology proves that there was a time when neither plants, nor animals, nor man existed; but both the Scriptures and geology are silent as to the period when the fiat of the Creator first called our earth and the planetary systems into being. It was, doubtless, in very remote antiquity, but the commencement is known only to Him who has neither "beginning of years, nor ending of days."

Thus the consistency of geology with the early Scripture history is susceptible of a perfect and triumphant defence, but it is not to be found in the refinements of exegesis, nor in the forced solution of a general deluge, which is entirely unsatisfactory, and, indeed, impossible, as a cause of the regular formations of the earth, immensely varied as they are, and exuberant in the relics of many *successive* races of the animals and vegetables of past ages. But this consistency is found in the regular induction from facts, in the just understanding of time, and in its extension back beyond the creation of man, so far as to embrace the innumerable events that have certainly happened in the material world.

To this conclusion the religious mind is fast approaching, and

its arrival at the goal of truth is as certain as the progress of time; and the period is near at hand, when the great deductions of Geology, like those of Astronomy, will be viewed by the intelligent and instructed as in perfect harmony with the Scriptures, and as affording new proofs of the wisdom, and goodness, and omnipotence of the ETERNAL BEING, who "*in the beginning created the heavens and the earth.*"

YALE COLLEGE,
NEWHAVEN, CONNECTICUT.

THE

WONDERS OF GEOLOGY.

LECTURE I.

1. Introductory. 2. Nature of Geology. 3. Harmony between Revelation and Geology. 4. Duration of geological Epochs. 5. Structure of the Earth. 6. Geographical Distribution of Animals and Plants. 7. Temperature of the Earth. 8. Nature of the Crust of the Globe. 9. Classification of Rocks. 10. Geological Mutations. 11. Connexion of Geology with Astronomy. 12. Nebular theory of the Universe. 13. Various states of the Nebulæ. 14. Formation of the Solar System. 15. Gaseous state of the Earth. 16. Geology elucidated by Astronomy. 17. Aerolites. 18. Origin of Aerolites. 19. Existing geological Agents. 20. Aqueous Agency: the effects of Streams and Rivers. 21. Deltas of the Ganges and Mississippi. 22. Formation of Fluviatile Strata. 23. Ripple-marks. 24. Lewes Levels. 25. Remains of Man in modern Deposits. 26. Peat Bogs. 27. Conversion of Peat into Coal. 28. Subterranean Forests. 29. Geological effects of the Ocean. 30. The Bed of the Ocean. 31. Effects of Currents. 32. Icebergs and Glaciers. 33. Incrusting Springs. 34. Incrustations. 35. Lake of the Solfatara. 36. Marble of Tabreez. 37. Stalactites and Caverns. 38. Consolidation of loose Sand. 39. Destruction of Rocks by Carbonic Acid. 40. Carbonic Acid in Caves. 41. Consolidation by Iron. 42. Recent Limestone of the Bermudas. 43. Fossil human Skeletons. 44. Isle of Ascension. 45. Drifted Sand. 46. Formation of recent Sandstone. 47. Siliceous depositions. 48. The Geysers of Iceland. 49. Siliceous Thermal Waters of New Zealand. 50. Artificial Solution of Silex. 51. Hertfordshire Pudding-stone. 52. Effects of high Temperature. 53. Volcanic agency. 54. Subsidence and Elevation of the Temple at Puzzuoli. 55. Historical Evidence, 56. Causes of these changes. 57. Elevation of the Chilian Coast. 58. Raised Seabeach at Brighton. 59. Elevation of Scandinavia. 60. Mutations in the relative Level of Land and Sea. 61. Retrospect.

1. Introductory.—An eminent philosopher* has justly remarked, that in order to obtain a proper sense of the interest and importance of any science, and of the objects which it embraces, nothing more is necessary than the intent and persevering study of them; for such is the consummate per-

* Professor Sedgwick.

fection of all the works of the Creator, that every inquirer will discover a surpassing worth, and grace, and dignity, in that especial department of knowledge to which he may peculiarly devote his attention. Whatever walk of philosophy he may enter, that will appear to him the path which is the most enriched by all that is fitted to captivate the intellect, and to excite the imagination. Yet before we can attain that elevation from which we may look down upon and comprehend the mysteries of the natural world, our way must be steep and toilsome, and we must learn to read the records of creation in a strange language. But when this knowledge is once acquired, it becomes a mighty instrument of thought, by which we are enabled to link together the phenomena of past and present times, and obtain a domination over many parts of the natural world, by comprehending some of the laws by which the Creator has ordained that the actions of material things shall be governed.

In the whole circle of the sciences, there is none that more strikingly illustrates the force and truth of these remarks than Geology; none which offers to its votaries rewards so rich, so wondrous, and inexhaustible. In the pebble under our feet, and in the rude mass of rock or clay in cliff or quarry, the uninstructed eye would in vain seek for novelty or beauty; like the adventurer in Eastern fable, the inquirer finds the cavern closed to his entrance, and the rock refusing to give up the treasures entombed within its stony sepulchre, until the talisman is obtained that can dissolve the enchantment, and unfold the marvellous secrets which have so long lain hidden.

2. NATURE OF GEOLOGY.— To the mind that is unacquainted with the nature and results of geological inquiries, and which has been led to believe that the globe we inhabit is in the state in which it was first created, and that, with the exception of the effects of a general deluge, its surface has undergone no material change, many of the facts to be

noticed in the course of these lectures may appear almost incredible, and the inferences drawn from their investigation be regarded as the vagaries of the imagination, rather than as the legitimate deductions of sound philosophy. If, therefore, it be absolutely necessary, as it unquestionably is, that in the pursuit of knowledge of any kind, before even experience can be employed with advantage, we must dismiss from our minds all prejudices, from whatsoever source they may arise, this mental purification becomes the more indispensable in a science like geology, in which we meet at the very threshold with facts so novel and astounding; facts which prove, that, though man and other living things be, as it were, but the creation of yesterday, the earth has teemed with numberless forms of animal and vegetable life during myriads of ages ere the existence of the human race.

Geology may be termed the physical history of the earth, —it comprehends the investigation of the mineral structure of our globe, and the characters and causes of the various changes which have taken place in the organic and inorganic kingdoms of nature. It has been emphatically denominated by one of our most distinguished philosophers the sister science of astronomy. But, relating as it does to the history of the past, and carrying us back, by the careful examination of the relics of former ages, to periods so remote as to startle all our preconceived opinions of the age of our planet, the fate of its early cultivators has resembled that of the immortal Galileo and the astronomers of his times; and for a similar reason, namely, the supposed discrepancy between the discoveries and inferences of this science, and the Mosaic cosmogony.

3. Harmony between Revelation and Geology.—There was a time when every geologist was compelled to defend himself against imputations of this kind; and it is deeply to be regretted, that there still exists in the minds of many well-meaning persons a prejudice against the study

of geology, from a mistaken apprehension, lest it should weaken our belief in the revealed word of God; for they assume that the results of geological inquiries and the Mosaic account of the creation of the world are utterly at variance with each other. But, convinced as I am that there never can be any collision between the doctrines of the purest piety and those of sound philosophy, and that prejudices have been created and perpetuated by authors who, falsely styling themselves geologists, have mixed up their own vague and erroneous notions with the history of the earth as given by the inspired writer,—attempting, with the presumption of ignorance, to account for that which lies beyond the reach of human investigation, and to explain it by evidence equally misapprehended and misapplied, — I would most unequivocally assert, that a just view of the nature and limits of geological science warrants no such reproach. Abandoning all attempts to explain the inexplicable, or to reconcile the irreconcilable, it confines itself to its legitimate purpose of accumulating and investigating facts, of pointing out analogies, and indicating the inferences to which they lead; "this is far different from the presumption which would fain prove the truth of Scripture by physical evidence, or the weakness that would found a system of natural philosophy on the inspired record."

Nothing is more unwarrantable than attempts to identify theories in science with particular interpretations of the sacred text; and the caution of Lord Bacon, uttered a century and a half before geology even had a name, cannot be too often repeated. "Let no man," said he, "upon a weak conceit of sobriety, or an ill-applied moderation, think or maintain that a man can search too far, or be too well studied in the book of God's word, or the book of God's works,—divinity or philosophy: but rather let men endeavour an endless progress or proficiency in both; only let them beware that they apply both to charity and not to arrogance—

to use and not to ostentation; and again, *that they do not unwisely mingle or confound these learnings together.*" Deeply impressed with the necessity of strictly obeying this admonition, I have, in all my written and oral discourses on geology, confined myself to a simple statement of the opinions of certain eminent philosophers and divines on this subject —men alike distinguished for their piety and learning, and who have cultivated with ardour this department of natural science, and have expressed their conviction of its high importance and beneficial influence upon the mind—in the hope that such evidence would be a sufficient and direct reply to the absurd and unfounded charges brought against geology. On the present occasion, I shall content myself with the following extract from a sermon by the Bishop of London: "*As we are not called upon by Scripture to admit, so neither are we required to deny the supposition, that the matter, without form and void, out of which this globe was framed may have consisted of the wrecks and relics of more ancient worlds, created and destroyed by the same Almighty Power which called our world into being, and will one day cause it to pass away.*"*

Thus, while the Bible reveals to us the moral history and destiny of our race, and instructs us that mankind and the existing races of beings have inhabited the earth but a few thousand years, the physical monuments of our globe bear witness to the same truth; and, as astronomy unfolds to us innumerable worlds not spoken of in the sacred records, geology in like manner proves, not by arguments drawn from analogy, but by incontrovertible physical evidence, that there were former conditions of our planet, separated from each

* Sermons, by Dr. Charles James Blomfield, Bishop of London. 8vo. 1829. The reader should also consult Pye Smith's "Geology and Scripture" (Bohn), 1852; Hugh Miller's "Lecture on Geology," 1855; and J. D. Dana's Review of Lewis's "Six Days of Creation," published in 8vo, Andover, U. S., 1856.

other by vast intervals of time, during which this world was teeming with life, ere the creation of man and the animals which are his contemporaries.

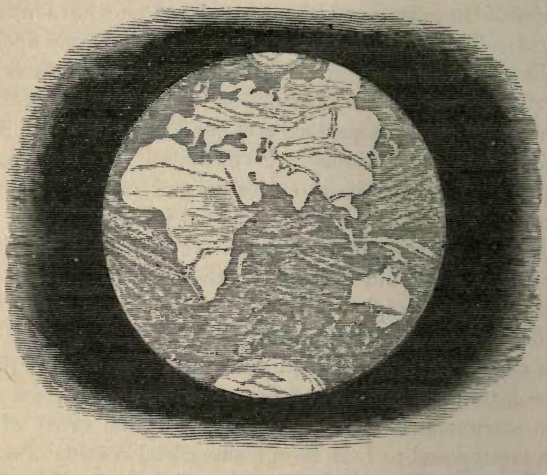
4. DURATION OF GEOLOGICAL EPOCHS.—At the first step we take in geological investigations, we are struck with the immense periods of time which the phenomena presented to our view must have required for their production, and the incessant changes which appear to have been going on in the natural world. But we must remember that time and change are great only with reference to the faculties of the beings which note them; the insect of a day, contrasting its ephemeral life with that of the flowers on which it rests, would attribute an unchanging permanence to the most evanescent of vegetable forms; while the flowers, the trees, and the forests would ascribe an endless duration to the soil on which they grow: and thus, uninstructed man, comparing his transient earthly existence with the solid framework of the world he inhabits, deems the hills and mountains around him coeval with the globe itself. But with the enlargement and cultivation of his reasoning powers, man takes a more just, comprehensive, and enlightened view of the wonderful scheme of creation; and, while in his ignorance he imagined that the age and duration of this planet were to be measured by his own brief span, and arrogantly deemed himself alone the object of the Almighty's care, and that all things were created solely for his pleasures and necessities, he now becomes conscious of his own insignificance and dependence, and entertains more correct ideas of the omnipotence and goodness of his Creator. And, while exercising his high privilege of being the only creature endowed with the capacity of contemplating and understanding the wonders of the natural world, he learns that most important of all lessons—to doubt the evidence of his senses, until confirmed by cautious and patient observation.

With these introductory remarks I proceed to the con-

sideration of the subjects selected for the present discourse, premising, that, from the magnitude and diversity of the objects embraced by geology, it is scarcely possible to offer, in the space assigned to a course of popular lectures, even an epitome of the marvels which modern researches have brought to light. This consideration, therefore, must be my apology for the concise manner in which many interesting facts will be noticed; and I would beg of you to consider that lectures of this kind can only present a general view of the philosophy of geology; that they are calculated to excite, rather than to satisfy, a rational curiosity, and cannot supersede the necessity of study, and of personal investigation.

5. STRUCTURE OF THE EARTH.—The globe we inhabit is a planetary orb, about twenty-four thousand miles in circumference, and of a spheroidal shape; its figure being such as a fluid body made to rotate on its axis would assume. The mean density is five times greater than that of water; that of the interior being double that of the solid external case. From astronomical observations, the original crust of the earth is supposed to have been a superficial coating of solidified matter, produced by the cooling of the surface of an incandescent fluid globe; and on this shell or crust have been slowly accumulated, during the lapse of innumerable ages, the rocks and strata which form the more immediate objects of geological investigation. The thickness of the solid crust of the earth is computed at from 800 to 1000 miles, but it is not supposed that this shell is uniform in extent or density; on the contrary, it is probable that it is cavernous, and that liquid masses of mineral matter, in various states of fluidity and incandescence, are distributed throughout the interior of the globe. Some of these subterraneous lakes of molten rock are probably isolated; others may communicate with each other by channels more or less pervious; and the extensive distribution of such sources of heat is supposed to account for the phenomena of earthquakes and volcanos,

and for the constant increase of temperature beneath the surface of the earth, in proportion to the depth that is reached.*



LIGN. 1.—THE SUPPOSED APPEARANCE OF THE EARTH AS SEEN FROM THE MOON.

(From Sir H. De la Beche's Theoretical Geology.)

The earth's surface is computed at 190 millions of square miles; of which three-fifths are covered by seas, and another large proportion by vast bodies of fresh water, by polar ice, and eternal snows; so that, taking into consideration sterile tracts, morasses, &c., scarcely more than one-fifth of the surface of the globe is fit for the habitation of man and terrestrial animals.† The area of the Pacific Ocean alone is estimated to be equal to the entire surface of the dry land.

* See the profound investigations "On the state of the interior of the Earth," by William Hopkins, Esq., *Philos. Trans.* for 1839 and 1842; and "On the Earth's temperature," *Journ. Geol. Soc.*, vol. viii., p. 56; see also his Presidential Address in the same volume.

† Bakewell's Geology.

The distribution of the land is exceedingly irregular, the greater portion being situated in the northern hemisphere, as a reference to a terrestrial globe, or a map of the world, will clearly demonstrate.

In a geological point of view, dry land is that portion of the earth's crust which is now above the level of the water, beneath which it may again disappear; and from accurate calculations it is proved, that the whole of the materials composing the present land might be distributed over the bed of the ocean in such manner that the surface of the globe would present an uninterrupted sheet of water; thus we perceive that every imaginable distribution of land and water may have taken place, at different periods, in the earlier ages of our planet.

6. GEOGRAPHICAL DISTRIBUTION OF ANIMALS AND PLANTS.—The investigation of the laws which govern the geographical distribution of animals and vegetables is highly interesting; but, as my limits compel me to be brief, I must refer you to Sir C. Lyell's "*Principles of Geology*" for a full consideration of the subject. It will be sufficient for our present purpose to state, that, although it might have been expected, all other circumstances being equal, that the same animals and plants would be found in places of like climate and temperature, this identity of distribution does not exist. When America was first discovered, the indigenous quadrupeds were all dissimilar to those of the Old World. The elephant, rhinoceros, hippopotamus, giraffe, camel, horse, buffalo, lion, tiger, &c., were not met with on the new continent; while many of the American mammalia, as the llama, jaguar, coati, sloth, &c., were unknown in the old. New Holland contains, as is well known, a most singular assemblage of mammalia, consisting of more than forty species of marsupial animals, of which the kangaroo is a familiar example. The islands of the Pacific Ocean possess no indigenous quadrupeds, except hogs, dogs, rats, and a few bats.

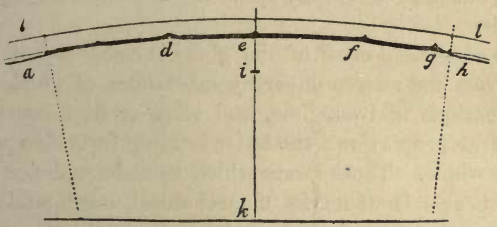
The distribution of vegetable life, though perhaps more arbitrarily fixed by temperature and by local influences than that of animals, presents many anomalies. From numerous observations, however, it is supposed that vegetable creation took place in different centres, each of which was the focus of a peculiar genus or species; for many plants have a local existence, and vegetate naturally in one district alone; thus the cedar of Lebanon is indigenous on that mountain, but does not grow spontaneously in any other part of the world. It is also ascertained that certain great divisions of the vegetable kingdom are distributed over particular regions: we shall have occasion to refer to this subject in the lecture devoted to the consideration of fossil plants.

7. TEMPERATURE OF THE EARTH.—The temperature of the surface of the globe depends on the action of solar light and heat; hence the difference in the seasons, and climates of various latitudes; but there are many causes which modify the distribution of the sun's influence, and produce great local variations: under equal circumstances, however, the temperature is found progressively to diminish from the equator to the poles. There is also an internal source of heat, the cause of which has not yet been determined, but is supposed to be connected with the original constitution of our planet. It has been ascertained, by careful experiments, that below the point to which the solar influence can penetrate, there is, almost everywhere, an invariable increase of temperature, amounting to 1° of Fahrenheit for every 54 feet of vertical depth: it is therefore possible that at 100 miles beneath the surface of the earth, even the least fusible rocks and minerals may be in a melted state.

8. NATURE OF THE CRUST OF THE GLOBE.—The total thickness of that portion of the rocks and strata accessible to human observation, reckoning from the highest mountain peaks to the greatest natural or artificial depths, is variously estimated at from ten to fifty miles. As the earth is nearly

eight thousand miles in diameter, the entire series of strata hitherto explored is, therefore, but very insignificant compared with the magnitude of the globe; bearing about the same relative proportion as the thickness of this paper to an artificial sphere a foot in diameter; the inequalities and crevices in the varnish of such a ball would, in fact, be equal in proportionate size to the highest mountains and deepest valleys.

The depth of the crust of the earth, and the greatest inequalities of its surface, as compared with its mass, are ex-



LIGN. 2.—DIAGRAM TO ILLUSTRATE THE PROPORTIONATE THICKNESS OF THE EARTH'S CRUST.

pressed in the annexed diagram.* The line from *e* to *k* represents a depth of 500 miles; from *e* to *i*, 100 miles; from *e* to the line *l*, *l*, 45 miles above the surface, the supposed limit of the earth's atmosphere; and the dark line, *a*, *h*, represents a thickness of ten miles. The points *d*, *e*, *f*, *g*, indicate the altitude of the highest mountains in the world;† the depth of the sea is shown by the line at the extremities of the arc, *a*, *h*. As a thickness of 100 miles so far exceeds that of the

* To preserve as far as possible the language and spirit of the original lectures, the references to the diagrams and specimens are retained.

† The highest peak of the Alps, and of Europe, is Mont Blanc, which is 15,660 feet above the level of the sea; of the Andes, Chimborazo, which is 21,425 feet; and of the Himalayas, Deva-dhunga, estimated at 29,002 feet, being more than five miles of perpendicular altitude.

whole of the strata that are accessible to human observation, we cannot doubt that disturbances of the earth's surface, even to ten times the depth of those which come within the scope of geological investigation, may take place, without in any sensible degree affecting the entire mass of the globe.* If these facts be duly considered, the mind will be prepared to receive one of the most striking propositions in modern geology—namely, that the highest mountains were once beneath the sea, and have been raised to their present situations by subterranean agency,—some slowly, others suddenly, but all, geologically speaking, at comparatively recent periods.

The superficial crust of the globe is composed of numerous layers and masses of earthy substances, of which various combinations of iron, lime, and silex or flint constitute a very large proportion; the latter forming forty-five per cent. of the whole. Those strata which have been deposited the latest bear evident marks of mechanical origin, and are the water-worn ruins of older rocks; as we penetrate deeper, deposits of a denser character appear, which also exhibit proofs of having been formed by the action of water; but when we arrive at the lowermost accessible to observation,

* To convey a general idea of the relative magnitude of the inequalities of the earth's surface, Mr. Fairholme suggests the following ingenious method. If we form a scale on the sand of the sea-shore in the proportion of an inch to a mile, we shall have a circle of 8000 inches, or 222 yards, in diameter, which, when marked out with small stakes, appears a very large area. Placing ourselves upon any part of this circumference, we have an opportunity of taking a just, though microscopic, view of the surface. The highest mountains in the world would be represented by a little ridge five inches high; the profound abyss of the ocean by a groove of the same depth; while the medium inequality of sea and land would not exceed one inch. To form an idea of smaller objects, we must examine an inch scale, finely graduated, by the aid of a microscope, and we shall then find that the tallest man would be about the 880th part of an inch in height—the size of the smallest animalcule observed in fluids by the aid of the most powerful microscope.

a crystalline structure generally prevails; and, while in the upper stratified rocks the remains of animals and vegetables are found in profusion, in the ancient crystalline masses all traces of organic forms are absent.

9. CLASSIFICATION OF ROCKS AND STRATA.—In the infancy of the science these remarkable facts gave rise to an ingenious theory, which, being founded on insufficient data, has proved untenable. It will, however, be requisite briefly to explain this hypothesis, as some of the terms still employed in geological nomenclature refer to the speculations it suggested. According to this theory the mineral masses composing the earth's crust are separable into three grand divisions or groups, as follow:—

1st. *Primitive Rocks.*—In this group were comprised granite, syenite, porphyry, gneiss, micaschist, clayslate, &c. These are mostly of crystalline structure; and present themselves either in a massive form, as granite, or in a laminated or schistose condition; the schists often being vertical or steeply inclined. These are the lowermost rocks, and constitute the foundation on which all the newer strata have been deposited; they also attain the highest elevations on the surface of the globe. They were termed "primitive," because, from their structure, it was supposed that they had crystallized in the primæval ocean; and from the absence of organic remains, it was inferred that they were formed before the creation of animals and vegetables; but it is now certain that both granitic and schistose rocks may be of various ages; some of them are of igneous origin; and others are sedimentary deposits which have been altered by long exposure to a very high temperature; hence the latter are now termed *metamorphic.*

2nd. *Transition Rocks.*—These were the next oldest rocks to the primary; they were regarded as partly crystalline and partly composed of materials derived from the primary

rocks; and their stratification was described as less steep than that of the former. From these gradual changes in their structure, and from their containing the fossilized remains of animals and plants, they received the name of *transition*, because it was assumed that they had been deposited at a period when the land and sea were passing into a state fit for the reception of organized beings. Modern researches have, however, shown that, like some of the "primitive" rocks, these are strata which often have been altered by the effects of heat under great pressure. The "transition" rocks comprise what are now known as "Cambrian," "Silurian," and "Devonian," and these, together with the "Carboniferous" and "Permian," constitute the "Primary fossiliferous rocks," or "Palæozoic system" of modern geologists.

3rd. *Flœtz or Secondary Rocks.*—The "flat" or horizontally stratified deposits succeeded the "transition" rocks. These strata originated from the destruction of more ancient rocks, and have been deposited in the basins of lakes, bays, and estuaries, and in the profound depths of the ocean, by the action of rivers and seas. They abound in the mineralized remains of animals and plants. The chalk is the uppermost or most recent of this group of formations. As the sedimentary rocks have manifestly been formed by the agency of water, it is clear that they were originally deposited in horizontal, or nearly horizontal, layers or strata, although by far the greater portion has since been broken up, and thrown in directions more or less inclined to the horizon.

Modern geologists have recognised a separate system of deposits above the secondary formations, namely, the *Tertiary* strata, which were by the older geologists confounded with the *Alluvial Deposits.*

4th. *Tertiary Deposits.*—These strata lie upon and fill up depressions or basins of the chalk and older rocks; they con-

sist of the detritus of more ancient beds, and of the relics of shells, plants, zoophytes, crustacea, fishes, &c.: and in them, with but two or three exceptions, the bones of mammalia first appear.

5th. *Alluvial Deposits.**—Of a later formation than the tertiary, are those irregular accumulations of alluvial or water-worn and drifted materials which are spread over the surface of almost every country. In the newest of these beds are found remains of existing races of animals and plants, which, in the most ancient, are associated with those of extinct genera and species.

Even a cursory study of the strata affords convincing proofs of a former condition of animated nature widely different from the present. We have evidence of a succession of periods of unknown duration, in which both the land and the sea teemed with forms of existence that have successively disappeared and given place to others; and these again to new races, more nearly related to those which now inhabit the earth, until at length traces of existing species appear.

10. GEOLOGICAL MUTATIONS. — From this view of the mineral structure of our planet we learn, at least so far as the limited powers of man can penetrate into the history of the past, that the distribution of land and water on the earth's surface has been undergoing perpetual mutation; yet that, through a vast period of time, its physical condition has not materially differed from the present. We find that the dry land has been clothed with vegetation, and tenanted by appropriate inhabitants; and that the seas and the rivers and lakes of fresh water have swarmed with living things; that at remote epochs, though animals and vegetables existed, the species were distinct from those that now abound, and

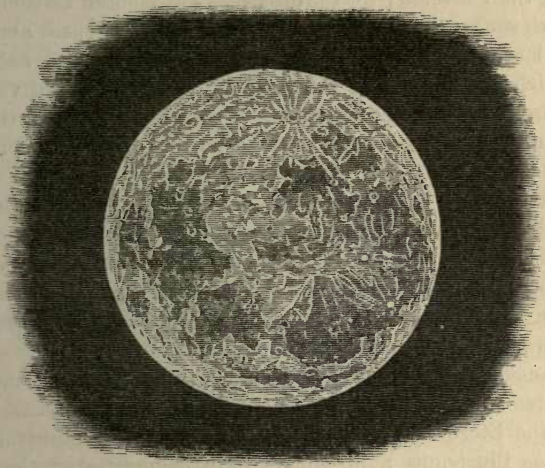
* The terms *diluvial* and *drift* are commonly employed to denote the most ancient of these deposits; and that of *alluvial*, the more recent, in which existing species of animals only occur.

the greater number fitted to live in a different climate than that which now prevails in the regions where these relics are entombed; and lastly, that in the lowest and most ancient beds, all traces of mechanical action, and of animal and vegetable organization, are absent; in other words, have either never existed or *have been altogether obliterated.*

11. CONNEXION OF GEOLOGY WITH ASTRONOMY.—Before entering upon that department of the subject to which the term Geology is commonly restricted, it will facilitate our comprehension of many of the phenomena that will come under our notice, if in this place we endeavour to penetrate the mystery that veils the earliest condition of the earth; but this we shall in vain attempt, if we restrict our observations to the physical phenomena observable in our own planet. Here Geology leads to Astronomy, and teaches us to contemplate the kindred spheres around us for the elucidation of the early history of the globe, and to regard the earth but as an attendant satellite on a vast central luminary. The solar system consists of the sun, which is a mass of solid matter surrounded by a luminous atmosphere, or nebulosity,—of eight planets and numerous planetoids, which revolve around it in various periods,—of eighteen satellites,—and of numerous comets, three of which do not pass beyond the orbits of the principal planets. The earth is the third in distance from the sun, and in bulk, as compared with that body, of the size of a pea to that of a globe two feet in diameter; and it has a satellite, the moon, which revolves round it.

Upon examining the moon with a powerful telescope, we perceive that its surface is diversified by hills and valleys, and presents a congeries of mountains, many of which are manifestly volcanic, lava-currents being distinctly visible. We see in fact a torn, rugged, sterile area, studded with craters, and scarred by rents and chasms, and having such an aspect as we may conceive would be presented by our earth, were the pinnacles of the granite-mountains unabrad-

ed, and the valleys bare, and not covered and partially filled up by sedimentary deposits.* But there is no evidence of the presence of either air or water in the moon.



LIGN. 3. TELESCOPIC VIEW OF THE MOON.

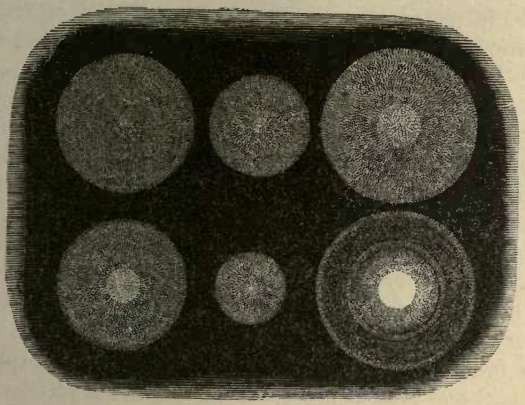
12. NEBULAR THEORY OF THE UNIVERSE.—In the original condition of the solar system, it is supposed that the sun was the nucleus of a nebulosity, or luminous mass, which revolved on its axis, and extended far beyond the orbit of the most distant of the planets; these bodies having then no existence. The temperature gradually diminished, and, the nebula contracting by refrigeration, the rotation increased in rapidity, and zones of nebulosity were successively thrown off, in consequence of the centrifugal force overpowering the central attraction: the condensation of these separated masses

* See Appendix A.

constituted the planets and satellites. This view of the conversion of gaseous matter into planetary bodies is not limited to our own system; it extends to the formation of the innumerable suns and worlds which are distributed throughout the Universe; for the discoveries of modern astronomers have shown, that every part of the realms of space abounds in large expansions of attenuated matter (termed *nebulæ*), which are irregularly reflective of light, and are of various figures, and in different states of condensation, from that of a diffused luminous mass to the condition of suns and planets like the earth. (See Appendix B.)

It must be admitted that this hypothesis is astounding,—and we may well demand if man, the ephemeron of the material world, can indeed measure the vast epochs which mark the progressive development of suns and systems? The master-minds of Laplace and Herschel have effected this wonderful achievement, and explained the successive changes by which it seems probable that suns and planetary systems are formed, through the agency of the sublime laws of the Eternal. By laborious and unremitting observations, those illustrious philosophers have demonstrated the progress of nebular condensation, not indeed from the appearances presented by a single nebula (for the process, probably, can only become sensible through the lapse of ages), but by observations on the almost endless series of related contemporaneous objects that appear in every varied state of progression, from that of a cloud of luminous vapour to the most dense and mighty orbs that appear in the firmament. As the naturalist in the midst of a forest, though unable by a glance to discover that the trees around him are in a state of progressive change, yet perceiving that there are plants in different stages of growth, from the acorn just bursting from the soil to the lofty oak that stands the monarch of the woods, infers, from the succession of changes thus at once presented to his view, the progression of vegetable life, though ex-

tending over a period far beyond his own brief existence,—in like manner, the astronomer, by surveying the varied conditions of the heavenly bodies around him, can, by careful induction, determine the nature of those changes, which,



LIGN. 4.—TELESCOPIC APPEARANCE OF VARIOUS NEBULÆ.

as regards a single nebula, the human mind would otherwise be unable to ascertain. And thus have been traced from nebular masses of absolute vagueness, to others which present form and structure, the effects of the mysterious law which appears to govern the stupendous celestial phenomena that are constantly taking place.*

* Although, by the enormous powers of the telescope constructed by the Earl of Rosse, it has been ascertained that several of Herschel's nebulæ are clusters of stars, and therefore that probably other supposed nebular masses may be brought into the same category, the theory explained in the text will only be modified, not disproved thereby.

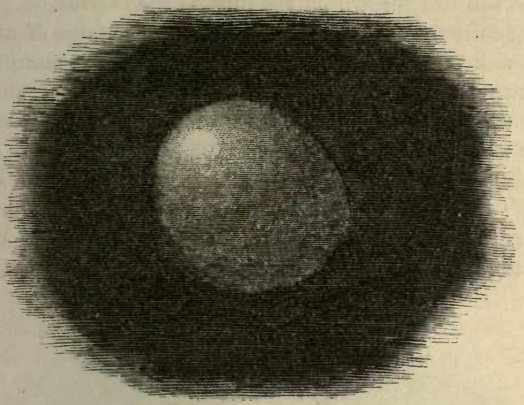
13. VARIOUS STATES OF THE NEBULÆ.—Some of the nebulæ appear as mere clouds of attenuated light; others as if curdling into separate masses; while many seem to be assuming a spheroidal figure. Others again present a dense central nucleus surrounded by a luminous halo; and a series may thus be traced, from clusters of round bodies with one or more increased points of condensation, or of central illumination, to separate nebulæ with single nuclei, and with rings,—to a central disk constituting a nebular star,—and finally to an orb of light with a halo like the sun!

In the comets, those nebular bodies which belong to our own and other systems, we have evidence that, even in the most diffused state of the luminous matter, the masses which it forms are subservient to the laws of orbicular motion: of this fact an interesting proof is afforded by Encke's comet (*Lign.* 5), that mere wisp of vapour, which in a period but little exceeding three years revolves around the central luminary of our system.

This beautiful theory of Laplace and of Herschel explains by an easy and evident process the formation of planets and satellites, and accounts for the uniform direction of their revolutions; and not only is it inferred that such is the law which the Creator has established for the maintenance and government of the Universe, but also that upon mechanical principles such nebulæ must of necessity be consolidated into planetary bodies.

14. FORMATION OF THE SOLAR SYSTEM.—In accordance with this hypothesis, our sun is regarded as a planetary orb with a luminous atmosphere, the central nucleus of a nebulosity which originally extended to the extreme verge of our planetary system. During the condensation of this nebula the planets were successively thrown off; the most distant, Neptune, being the first or most ancient, followed by Uranus, Saturn, Jupiter, the asteroids or planetoids, of which forty-

two have been already discovered, Mars, the Earth, Venus, and Mercury; the satellites, as distinct worlds, being the

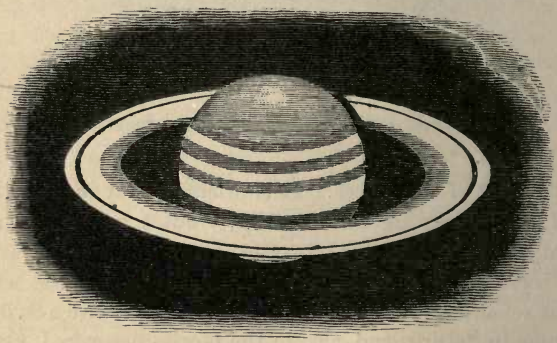


LIGN. 5.—TELESCOPIC VIEW OF ENCKE'S COMET.

most recent of the whole. It is inferred, that in any given state of the rotating solar mass the outer portion or ring might have its centrifugal force exactly balanced by gravity; but increased rotation would throw off that ring, which might sometimes retain its figure, of which we have a striking example in Saturn, and also in the newly-discovered planet Neptune. This result, however, could not take place unless the annular band were of uniform composition, which would rarely be the case; hence the ring would most generally divide into several portions, which might sometimes be of nearly equal bulk, as in the planetoids, while in others they might coalesce into a single mass. The solar nebulæ, thus separated at various periods, and constituting planets in a gaseous state, would necessarily have a rotatory motion, and

revolve in varying orbits around the central nucleus; and, as refrigeration and consolidation proceeded, each body might project entire annuli, or rings, and satellites, in like manner as the sun had thrown off the planets themselves.

In addition to the appearance of various states of attenuation and of solidity presented by the nebulæ, the orbs of our own system afford evidence of corresponding gradations of density. The planets near to the sun are denser than those which are more distant: thus Mercury, which is the nearest, is the heaviest, being almost thrice as dense as the Earth: while the density of Jupiter, which is far removed, is only one-third that of our planet; and Saturn, which, with the exception of Uranus and Neptune, is the remotest,



LIGN. 6.—TELESCOPIC VIEW OF SATURN.

is but little more than one-eighth as dense, and is supposed to be as light as cork.*

* Introduction to Astronomy, by Sir J. F. W. Herschel. Those who feel desirous of more ample information on this subject should consult "*Views of the Architecture of the Heavens*," by Dr. Nichol, Professor of Practical Astronomy in the University of Glasgow.

You will at once perceive that this theory can in no wise affect the sublime truth that the Universe is the work of an all-wise and omnipotent Creator; "For let it be assumed that the point to which this hypothesis leads us is the ultimate boundary of physical science,—that the nearest glimpse we can attain of the material universe displays it to us as occupied by a boundless abyss of attenuated matter; still we are left to inquire how space became less occupied—whence originated matter thus luminous? And, if we are able to establish by physical proofs, that the first fact which the human mind can trace in the history of the heavens is that '*there was light*,' we are irresistibly led to the conclusion, that ere this could take place, 'GOD SAID, *Let there be light*.'" *

This theory of the condensation of nebular matter into suns and worlds, marvellous as it may appear, will be found on due reflection to suggest the only rational explanation of the phenomena observable in the sidereal heavens, and in our own globe, according to the present state of the physical sciences; while its beautiful simplicity is in correspondence with the unity of design so manifest throughout the works of the Eternal. †

* Professor Whewell.

† Dr. Pye Smith, in his able commentaries on the "Relation between Scripture and Geological Science" (lately republished in Bohn's Scientific Library), has the following remarks upon this subject: "The nebular hypothesis, ridiculed as it has been by persons whose ignorance cannot excuse their presumption, is regarded by some of the finest and most Christian minds as in the highest degree probable. If I may venture to utter my own impression, I must profess it as the most reasonable supposition, and the correlate of the nebular theory, that GOD originally gave being to the primordial elements of things, the very small number of simple bodies, endowing each with its own wonderful properties. Then, that the actions of those properties, in the way which his wisdom ordained, and which we call laws, produced, and is still producing, all the forms and changes of organic and inorganic nature; and that the series is destined to proceed,

15. GASEOUS STATE OF THE EARTH.—Though it may be difficult to the unscientific inquirer to comprehend that our planet once existed in a gaseous state, this difficulty will vanish upon considering the nature of the changes to which all the materials composing the earth are constantly subjected. Water offers a familiar example of a substance existing on the surface of the globe in the separate states of rock, fluid, and vapour; for water consolidated into ice is as much a rock as granite or the adamant, and, as we shall hereafter have occasion to remark, has the power of preserving for an indefinite period the remains of any animals and vegetables imbedded therein. Yet simply upon an increase of temperature, the glaciers of the Alps, and the icy pinnacles of the Arctic circles, disappear,—and by a degree of heat still higher, would be resolved into vapour,—and by other agencies might be separated into two invisible gases—oxygen and hydrogen. Metals may in like manner be converted into gases; and in the laboratory of the chemist, all kinds of matter easily pass through every grade of transmutation, from the most dense and compact to an aeriform state. We cannot, therefore, refuse our assent to the conclusion, that merely by the dissolution of the existing combinations of matter the entire mass of our globe might pass into a gaseous or nebular condition.

in combinations and multiplications ever new, without limit of space or end of duration, to the eternal display of HIS glory."

These remarks may be regarded as a philosophical enunciation of the hypothesis that has been termed "*organic creation by law*," or the formation of living beings from inorganic elements. But this theory is not at present substantiated, nor even sanctioned, by any unequivocal evidence: and this absence of all proof appears to me the serious and only legitimate objection to the reception of a doctrine which would explain many obscure physiological phenomena, and bring the laws of vitality into harmony with those which preside over the inorganic kingdom of nature. See the Appendix to my "*Thoughts on Animalcules*;" and Westminster Review, No. XC., article "*Revelations of the Microscope*."

16. GEOLOGY ELUCIDATED BY ASTRONOMY.—From the light thus shed by modern Astronomy upon many of the dark and mysterious pages of the earth's physical history, it appears probable that the dynamical changes which have taken place in our globe—all the transmutations of its crust revealed by geological investigations—may be referable to the operation of the one, simple, and universal law, by which the condensation of nebular masses into worlds, through periods of time so immense as to be beyond the power of human comprehension, is governed.

The internal heat of the globe,—the evidence afforded by the crystalline condition of the lowermost rocks of a prevailing higher temperature in an earlier state of the earth,—and the elevations and dislocations of its crust which have taken place, and are still going on,—all refer to such an origin, and to such a constitution of our planet, as that contemplated by the nebular theory. Nor is the elevatory process peculiar to the earth, for Venus, Mercury, and the moon exhibit evidence of a similar action; and in the two former the mountains are of an enormous altitude.* In a philosophical point of view, the present physical epoch of our globe "is that of the fluidity of water, which is the nebulous bed or stratum last condensed, and which exerts mechanical and chemical action upon the previously consolidated materials." †

17. AËROLITES.—Intimately connected with this division of the subject is the remarkable fact of the fall of foreign bodies, called aërolites, or meteoric stones, from the atmosphere. The specimen before us, for which I am indebted to Professor Silliman, is a fragment of a mass which fell at Nanjenoy, in Maryland, North America, a few years since. The following description of its descent, by an eye-witness,

* This subject is ably treated in Sir H. De la Beche's "Researches in Theoretical Geology."

† Dr. Nichol.

will serve to illustrate the ordinary phenomena which attend the appearance of these mysterious visitors.*

"On the 10th of February, between the hours of twelve and one o'clock, I heard an explosion, as I supposed of a cannon, but somewhat sharper. I immediately advanced with a quick step about twenty paces, when my attention was arrested by a buzzing noise, as if something was rushing over my head, and in a few seconds I heard something fall. The time which elapsed from my first hearing the report to the falling might have been fifteen seconds. I then went with some of my servants to ascertain where it had fallen, but did not at first succeed; however, in a short time the place was found by my cook, who dug down to the stone, which was discovered about two feet below the surface. It was sensibly warm, and had a sulphurous smell, was of an oblong shape, and weighed sixteen pounds and seven ounces; it had a hard, vitreous surface. I have conversed with many persons, living over an extent of perhaps fifty miles square; some heard the explosion, while others noticed only the subsequent whizzing noise in the air; all agree in stating that the sound appeared directly over their heads. The day was perfectly fine and clear. There was but one report heard, and but one stone fell, to my knowledge; there was no peculiar smell in the air: it fell within 250 yards of my house."†

18. ORIGIN OF AËROLITES.—Mrs. Somerville has the following interesting remarks on this subject:—"So numerous are the objects which meet our view in the heavens, that we cannot imagine a part of space where some light would not strike the eye: innumerable stars,—thousands of double and multiple systems,—clusters in one blaze with their ten thousands of stars,—and the nebulæ amazing us by the

* American Journal of Science.

† An analysis of this meteorite gave the following results:—*Oxide of Iron*, 24; *Oxide of Nickel*, 1.25; *Silica with earthy matter*, 3.46; *Sulphur, a trace*; = 28.71.

strangeness of their forms; till at last, from the imperfection of our senses, even these thin and airy phantoms vanish in the distance. If such remote bodies shone by reflected light, we should be unconscious of their existence; each star must then be a sun, and may be presumed to have its system of planets, satellites, and comets, like our own; and for aught we know, myriads of bodies may be wandering in space unseen by us, of whose nature we can form no idea, and still less of the part they perform in the economy of the universe. Nor is this an unwarranted presumption: many such do come within the sphere of the earth's attraction, are ignited by the velocity with which they pass through the atmosphere, and are precipitated with great violence to the earth. The fall of meteoric stones is much more frequent than is generally believed;* hardly a year passes without some instances occurring; and, if it be considered that only a small part of the earth is inhabited, it may be presumed that numbers fall into the ocean, or on the parts of the land uninhabited by civilized man.——The obliquity and velocity of the descent of meteorites, the peculiar substances of which they are composed, and the explosion attending their fall, show that they are foreign to our planet. Luminous spots, altogether independent of the phases, have been seen on the dark parts of the moon; these appear to be the light arising from the eruption of volcanos; whence it has been supposed that meteorites have been projected from the moon by the impetus of volcanic eruption. For, if a stone were projected from our satellite in a vertical line, with an initial velocity of 10,992 feet in a second—a velocity but four times that of a ball when first discharged from a cannon,—instead of falling back to the moon by the influence of gravity, it would come within the sphere of the earth's attraction, and revolve around it. These bodies, impelled either by the direction of

* According to Schriebers, it is probable that the phenomenon occurs not less than 600 times annually.

the primitive impulse, or by the disturbing action of the sun, might ultimately penetrate the earth's atmosphere and arrive at its surface. But from whatever source meteoric stones may come, it is highly probable that they have a common origin, from the uniformity, we may almost say identity, of their composition."*

The lunar origin of aërolites, above alluded to, has been adopted by Laplace and others; but, like Chaldni's hypothesis of their being minute planetary bodies revolving round the sun, and sometimes encountering the earth, it has great difficulties to contend with; and as yet very little is really known of the nature or origin of shooting stars.

These masses present a general correspondence in their chemical composition and appearance, having (with the exception of native iron) a crystalline character internally, and externally a black slaggy crust, as in this specimen from Nanjenoy.†

A mass of native iron containing *nickel* has been discovered in northern Asia, in an auriferous deposit, at a depth of about 30 feet; and a similar mass has been found imbedded among the Carpathian Mountains: both these masses are very like undoubted meteoric stones. But, as probably meteorites chiefly consisting of iron would be decomposed during the lapse of ages, the vestiges of such bodies in the strata must be necessarily rare. Other meteoric stones, however, composed mainly of silica, have been recorded; and Mr. E. W. Binney has published an interesting account of three such peculiar siliceous and probably meteoric stones, which have been collected from the coal measures of Lancashire and South Wales.‡ If so, we must conclude that

* Connexion of the Physical Sciences.

† There is a fine collection of aërolites in the gallery of minerals of the British Museum. See Mantell's "Fossils of the British Museum," p. 15.

‡ *Transact. Phil. Lit. Soc. Manchester*, vol. ix.

before the last arrangement of the earth's surface, meteoric stones had fallen upon it.

Baron Humboldt observes that aërolites afford the only direct experimental knowledge we possess of any of the specific properties or qualities of matter not belonging to our globe. Their direction and enormous velocity of projection (a velocity wholly planetary) render it more than probable, that these masses, enveloped in vapours and reaching the earth in a high state of temperature, are small heavenly bodies which the attraction of our planet has caused to deviate from their previous path. The aspect so familiar to us of these aërolites, and the analogy which their composition presents to minerals contained in the crust of the earth, are very striking. The inference to which they point appears to me to be, that the planetary and other masses were agglomerated in rings of vapour, and afterwards in spheroids, under the influence of a central body; and that, being originally integral parts of the same system, they consist of substances chemically identical.*

19. EXISTING GEOLOGICAL AGENTS.—Assuming then that our planet, when first called into being by the fiat of the Creator, was a gaseous mass, "without form and void," and destined through indefinite ages to undergo mutations which ultimately rendered it a fit abode for man and the animals which are his contemporaries, we proceed to investigate the nature and effects of the agencies by which its surface is still modified.

In this division of the subject it will be my object to explain in a clear and familiar manner some of those physical changes which, unheeded or unappreciated, are taking place around us; but which, operating on a large scale, and through a long period of time, are capable of producing effects that materially modify the earth's surface, and give rise to results

* *Cosmos;* a Sketch of a Physical Description of the Universe, by Baron Humboldt. (Translation. Bohn's Scientific Library.)

which, when viewed in the aggregate, fill the uninformed mind with astonishment, and lead it to call up imaginary convulsions and catastrophes to explain the result of some of the most ordinary operations of nature. As the simple lines that compose the alphabet constitute, when placed in combination, the mighty engine by which the master spirits of our race enlighten and benefit mankind, so natural processes, in themselves apparently inadequate to produce any important effects, become, by their combined and continued operation, an irresistible power, by which the dry land is converted into the bed of the ocean, and the bed of the ocean into dry land; thus fulfilling the universal law of nature, which subjects every particle of matter to incessant change.

Before proceeding further in this inquiry, I would notice an opinion, so generally prevalent that it may possibly be entertained by some of my readers, namely, that the phenomena which will come under our consideration have been occasioned by the deluge recorded in Scripture. But whatever may have been the modifications of the earth's surface produced by that catastrophe, they must on the present occasion be wholly excluded from our consideration, for the changes to which geological inquiries relate are of a totally different character, and referable to periods long antecedent to that miraculous event.

I have now to direct your attention to certain natural operations which, when properly investigated, will afford an easy explanation of facts, of the highest interest and importance, that present themselves at the first step we take in our inquiry,—will teach us how this limestone has been formed of brittle shells, and this marble filled with the coral to which it owes its beautiful markings,—how wood has been changed into stone, and plants and fishes have become enclosed in the solid rock. I have to explain to you that the ground on which we stand was not always dry land, but once constituted the bed of the sea,—that the hills, now so smooth and

rounded, and clothed with verdure, have been formed in the profound depths of the ocean, and may be regarded as vast tumuli, in which the remains of beings that lived and died in the early ages of the globe are entombed; and that the wealds of Kent and Sussex, those rich and cultivated districts which fill up the area between the chalk-hills of Sussex, Surrey, Kent, and Hampshire, were once the delta of a river, that flowed through a country which is now swept from the face of the earth—a country more marvellous than any that even romance or poetry has ventured to portray.

20. AQUEOUS AGENCY: THE EFFECTS OF STREAMS AND RIVERS.—The operations we have now to consider are produced by a substance, the most abundant in nature, and with the properties of which we are so familiar, that we but little appreciate the marvellous phenomena they present. This substance—which in one state constitutes vast islands and continents, forming masses that rival in transparency and brightness the rock-crystal or the diamond, and are more durable than granite, and so sterile as to afford no sustenance, even to the simplest forms of vitality—in another condition is invisible, and separates into two gases, which supply heat and light to organic bodies;—in a third state it exists as an elastic vapour, which yields to man a power far surpassing that of the fabled wand of the magician, enabling him to cross the ocean in spite of the elements, and traverse the land with a rapidity exceeding that of any other animal;—and lastly, it appears as a fluid which is the essential support of animal and vegetable life, and covers a large portion of the surface of our globe; affording in its profound abysses a habitation for the most colossal of existing animals, and containing in each drop myriads of the minutest beings which the aided eye of man is able to descry!—such are the wonderful properties of the substance that, in its fluid state, we term *water*, and the geological effects of which we now proceed to examine.

In pursuance of this object, we will first notice the changes produced on the surface of the land by the agency of streams and rivers. I need not dwell on those meteorological causes by which the descent of moisture on the surface of the earth is regulated; but will merely observe, that rivers are the great natural outlets by which the superfluous moisture of the land is conveyed into the grand reservoir, the ocean. And so exactly is the balance of expenditure and supply maintained, that all the rivers on the face of the earth, though constantly pouring their mighty floods into the ocean, do not affect its level in the slightest perceptible degree; we may therefore assume that the quantity of moisture evaporated from the surface of the sea and descending on the earth in rain and vapour is exactly equal to the sum of all the water in all the lakes and rivers in the world.* But though the quantity of fluid poured by the rivers into the basin of the ocean is again removed by evaporation, yet there is an operation silently and constantly going on, which becomes an agent of perpetual change. The rivulets which issue from

* The quantity of water that percolates into the earth from the surface is very great. It is well known that the water in mines varies with, and depends upon, the rain falling in the districts where they are situated. Seasons of heavy rain are followed by a great increase of water in a mine, and the reverse happens from a drought. The time which elapses before the effect of these causes manifests itself varies considerably, and depends on the mineralogical character and physical features of the country. In carboniferous limestone districts the percolation of rain-water is particularly rapid, so that a heavy fall of rain will often overpower the machinery sufficient for ordinary drainage. "In two mines in Flintshire, the steam-engines, after having been increased in speed from three or four strokes per minute to the extent of their power, about five times as many, were yet incapable of preventing the water from rapidly increasing and filling the workings. In these mines there are great cross-courses or faults, which can be traced several miles, and pour torrents of water into the veins; they are, in fact, channels for subterranean rivers, and the latter carry with them large quantities of sand and gravel, worn away from the rocks through which they pass."—*R. Taylor.*

the mountains are more or less charged with earthy particles, worn from the rocks and strata over which they flow; the united streams in their progress towards the rivers become more and more loaded with adventitious matter; and as the power of abrasion becomes greater, by the increase in the quantity and density of the mass of water, a large proportion of the materials is suspended in the fluid, and carried into the sea. If the current be feeble, much of the mud, and the larger pebbles, will be thrown down in the bed of the river, —hence the formation of alluvial plains, as for example those in the valleys of the Arun, the Adur, the Ouse, and Cuckmere, in this county (Sussex). But a great quantity is transported to the mouths of the rivers, and there forms those accumulations of the fluviatile spoils of the land which constitute deltas; the finest particles, however, are carried far into the sea, and, transported by currents and agitated by the waves, are at length precipitated into the profound and tranquil depths of the ocean. But rivers convey not only the mud and other detritus of the countries through which they flow; leaves, branches of trees, and other vegetable matter, and the remains of the animals that fall into the streams, with shells and other animal exuviæ, human remains, and works of art, are also constantly transported and imbedded in the silt and sand of the deltas and estuaries, and some of these remains are occasionally drifted out to sea, and deposited in its bed.

21. Deltas of the Ganges and Mississippi.*— The changes here contemplated, as they are going on in our own island, may appear insignificant, and incapable of producing any material effect on the earth's surface; but, if we trace the results in countries where the agents under review are operating on a larger scale, we shall at once perceive their importance, and that time only is required for the accumula-

* In the Philosophical Magazine for April 1853 is a very valuable paper by Mr. A. Tylor, on the increase of deltas, and the decrease of continents.

tion of strata equal in extent and alike in character with many of those ancient deposits which will hereafter come under our observation.

From experiments made with great care, it has been ascertained that the quantity of solid matter brought down by the Ganges and carried into the sea annually is 6,368,077,440 tons: in other words, a mass of solid materials surpassing in size and weight sixty times that of the great pyramid of Egypt; the base of that stupendous structure covering eleven acres, and its perpendicular height being 500 feet.* The Burrampooter, another river in India, conveys annually as much earthy matter into the sea as the Ganges. The waters of the Indus, as the late Sir Alexander Burns informed me, are alike loaded with earthy materials. In the vast rivers of America, the same effects are observable; the Mississippi, which flows through twenty degrees of latitude and seven of longitude, and drains a valley 3000 miles long and nearly 1000 broad, brings down whole forests and immense rafts, composed of trunks and branches of trees and drifted underwood, and transports them to its delta, which extends several hundred miles out to sea; and the area around the embouchure of that river is becoming shallower every day, by the sole agency of the causes now under consideration. The delta of this mighty stream is computed by Sir C. Lyell to be at least between 500 and 600 feet in depth, the area it covers nearly 14,000 square statute miles, and the solid matter annually added 2 billions 700 millions of cubic feet; and the period required for the formation of the deposits now composing the delta, at more than 60,000 years.†

In the sediments of these rivers, remains of the animals and plants of the respective countries are continually enveloped. It is therefore evident, that, should the deltas be-

* Lyell's Principles of Geology.

† Lecture on the Delta of the Mississippi, before the British Association, at Southampton, 1846.

come dry land, the naturalist could, by an examination of the animal and vegetable remains imbedded in the fluviatile sediments, readily determine the characters of the fauna and flora of the countries through which the rivers had flowed. We may here observe, that in tropical regions, where animal life is profusely developed, and but little under the control of man, the animal remains buried in the deltas are far more abundant than in those of European countries, which are thickly peopled and in a high state of civilization. The enterprising but unfortunate Lander informed me, just before he embarked on his last and fatal expedition to Africa, that many parts of the Quorra, or Niger, as far as the eye could reach, teemed with crocodiles and hippopotami; and so great was their number, that he was often obliged to drag his boat on shore lest it should be swamped by them.

It is unnecessary to dwell longer on these operations; it will suffice to have shown, that by the simple effect of running water great destruction and extensive modifications of the surface of the land are everywhere taking place, and at the same time fluviatile deposits are being formed on an extensive scale, and imbedding animal and vegetable remains. Thus, in the deltas of the rivers of England are found the bones and antlers of the deer, horse, and other domesticated animals, associated with the trunks and branches of trees and plants, river and land shells, human bones, and fragments of pottery and other works of art: while in those of the Ganges and the Nile, the remains of the animals and vegetables of India and of Egypt are respectively entombed.

22. Formation of fluviatile strata.—There is a circumstance connected with these facts which it is necessary here to consider. The quantity of water in streams and rivers varies considerably at different periods of the year; in the rainy season the rivers are overflowing, and the waters remarkably turbid: consequently the deposits are much greater at those periods than in the summer months, when

the currents are feeble, and the rivers shallow. In that part of the stream affected by the tides, there is also a constant flux and reflux of the waters, and from this cause the sediments must, to a certain degree, be periodical. Accordingly we find the silt and sand disposed in *strata* or layers, from the partial consolidation of the surface of one bed of mud, before the superincumbent layer was precipitated upon it. Thus wherever a fresh break takes place in a bank of consolidated silt in a delta, as for example in that of the Nile, it is easy to trace the deposits of each successive year, by means of the lighter earth on the top of each. When a portion is taken into the hand, it separates into layers; and, on closely examining the edges of these, very delicate thin lines are perceptible, showing a laminated structure, like those observable in the coal-shales. Judging from these layers, the annual deposits from the Nile appear to vary considerably, but the average thickness is little more than a quarter of an inch.*

Where a river terminates in an extensive estuary, the sea throws a covering of sand over the layer of mud brought down by the river; and frequently these alternate with the greatest regularity, the receding of the tide allowing the fresh water to deposit its mud, and the advance of the sea discharging sand and marine exuviæ over the surface.

23. RIPPLE-MARKS.—And here we may notice another phenomenon. Every one must have observed, when walking by the banks of a river at low water, or on the sands of the sea-shore, that, when the water has been agitated by the wind, the surface of the mud or sand is undulated, or furrowed over by the rippling of the waves, the marks presenting various appearances, according to the force and direction of the currents. Frequently, too, worms and molluscous

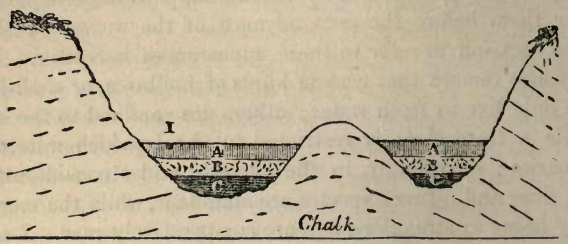
* Letter to Professor Silliman from an American who visited Egypt in 1834. See also Mr. L. Horner's Memoir on Egypt and the Nile, Phil. Trans. 1855.

animals crawl over and mark the surface with meandering lines and ridges; and these varied characters on the sand are preserved, if a thin layer of mud happens to be deposited over them before the next advance of the waves. I shall have occasion to refer to these appearances hereafter. We may also remark that certain kinds of mollusca, or shell-fish, can only live in fresh water; others are confined to the sea; while a third class is restricted to the brackish waters of estuaries; accordingly, in the deposits under consideration, the river and estuary species are abundant, while the marine only occur as stragglers, and are comparatively rare. Land-plants, and those which affect a marshy soil, as the equiseta or mare's-tails, reeds, rushes, &c., are likewise often accumulated in such quantities as to form beds of peat.

24. Lewes Levels.—It will serve to impress the subject more forcibly upon our minds, if we refer to some local example of fluvio-marine deposits: and, from its immediate vicinity to Brighton, I select that which occurs in the valley of the Ouse, near Lewes, which is one of several estuaries whence the sea has retired within the last eight or ten centuries. This tract is about eight miles in length from north to south, and varies in breadth from half a mile to two miles and a half. The valley is bounded by an amphitheatre of chalk-hills, into which the river enters through a gorge of the Downs on the north, near Offham, and, pursuing a tortuous course, flows between the towns of Lewes and The-Cliff, and discharges its waters into the sea at Newhaven. This alluvial plain is called *Lewes Levels*, and is here and there flanked on the east and west by headlands and ancient sea-cliffs; while a few insular mounds of chalk rise up through the fluviatile deposits, that have been accumulating during a long period of time. *Lign.* 7 represents a section of the valley of the Ouse, from east to west.

Here we have a depression (or *basin*, as it is termed by geologists) of chalk-strata, partially filled up by layers of

indurated mud or silt, the surface of which is clothed with verdure: the bed of the river (1) is situated near the east-



LIGN. 7.—SECTION ACROSS LEWES LEVELS.*

A. A. Silt, with river shells; B. B. Clay, with river and marine shells; C. C. Deposit with marine shells only.

ern chalk-cliffs. By numerous sinkings through the soil, carried from the surface down to the chalk-bottom, and the depth of which varied from fifteen to thirty feet, the deposits have been ascertained to be as follow:—

1. Bog-earth and peat, about five feet in thickness: formed of decayed twigs and leaves of hazel, oak, birch, &c., and enclosing trunks of large trees.
2. (A. A.)—Blue clay, or indurated mud, containing several species of fresh-water shells, like those which now inhabit the river and ditches; with numerous *indusiæ*, or cases of the larvæ of a species of *phryganea*, commonly termed caddis-worms. Bones of horses and deer have been found in the lower part of this bed.
3. (B. B.)—Clay containing fresh-water shells, with an intermixture of existing marine species, as the common cockle (*cardium edule*), tellina, &c.
4. (C. C.)—Blue clay, enclosing marine shells, viz. cockles, mussels, &c., without any intermixture of fluviatile species.—In this de-

* A *geological section* represents the internal structure of the earth on any given line, in a vertical direction; and is either, 1. *natural*, as seen in cliffs, precipices, &c.; 2. *artificial*, as in quarries, tunnels, and other excavations; or, 3. *theoretical*, when constructed from a combination of observations on the position of the strata in various distant localities.

posit a skull of the narwhal, or sea-unicorn (*Monodon monoceros*), and of the porpoise have been discovered.

From the nature of these sediments we learn that this valley was once an arm of the sea, and that the following sequence of physical changes has taken place :—

First, there was a salt-water estuary, inhabited by marine shell-fish of the same species as those now existing in the British Channel, and into which cetacea occasionally entered.

Secondly, the inlet grew shallow, the water brackish, and marine and fresh-water shells were mingled in its blue argillaceous sediment.

Thirdly, the shoaling continued until fresh water so much predominated, that fluviatile shells and aquatic insects could alone exist.

Fourthly, a peaty swamp was formed by the drifting of trees and plants from the forest of Andreadswald, which formerly occupied the entire Wealds of Sussex and the adjacent counties ; and terrestrial quadrupeds were occasionally embedded in the morass.

Lastly, the soil being inundated by land-floods at distant intervals only, became an oozy marsh, which has been gradually converted into a fertile tract of country.

Such are the natural changes which the river-valley of the Ouse has undergone, as shown by the character of the deposits which partially fill up this depression in the chalk ; and historical records confirm the geological evidence.* What further transmutations the plain of Lewes Levels is destined to undergo cannot be foretold. It may be, that some change in the relative level of the land and water along the Sussex coast will again convert the Levels into an arm of the sea, and the town of Lewes be once more a port. On the other hand, the physical agents of terrestrial change may lie dormant, and man, with the mighty powers of nature over which science has given him control, may include this alluvial plain in the grand line of communication that shall link together the metropolitan cities of France and of England,

* See "A Day's Ramble in and about the Ancient Town of Lewes," 1 vol. 8vo, 1846, by the Author.

and ere another century have passed away, these now verdant pastures may be covered with towns and cities, swarming with busy communities of the human race.

25. REMAINS OF MAN IN MODERN DEPOSITS.—But the sediments in the river-valleys often contain not only bones of deer, horse, boar, and other terrestrial animals, but also human skeletons, which are sometimes found enclosed in coffins of exceedingly rude workmanship; together with canoes,* and other relics of the early inhabitants of our island. This human skull was dug up at a great depth in the blue silt of Beeding Levels; it was enclosed, together with the other bones of the skeleton, in a coffin of oak, which was evidently of high antiquity, being formed of four rude planks, or rather hewn trunks of trees, held together by oaken pegs. The skull is of a dark bluish-brown colour,

* *Ancient British Canoe.* In 1835 a canoe was discovered at the depth of several feet in a bed of silt, that filled up an ancient branch of the river Arun, at North Stoke, near Arundel. It was presented by my noble friend, the late Earl of Egremont, to the British Museum. This canoe is nearly thirty-five feet in length, four and a half wide in the centre, three feet three inches broad at one extremity, and two feet ten inches at the other; and is about two feet deep. It is formed of a single trunk of oak, which has been hollowed out and brought to its present shape with great labour: it is evidently the workmanship of a very remote period, and in all probability was constructed by some of the earliest inhabitants of our island, before the use of iron or even brass was known: the original tree must have been fifteen or sixteen feet in circumference. Three projections, left in the interior of the boat, appear to have been designed for seats; it is manifest therefore that the persons who constructed this vessel were unacquainted with the art of forming boards. This canoe is so similar to some of those which were fabricated by the aborigines of North America, when first visited by Europeans, that we can have no hesitation in concluding that it was constructed in a similar manner; namely, by charring such portions of the tree as were to be removed, and scooping them out with stone instruments. No doubt this canoe belongs to the same period as the flint and stone instruments called *celts*, which are found in the tumuli on the South Downs.

like the bones of deer and horse found in similar deposits, an appearance attributable to an impregnation of iron; when first dug up, the interstices of the bones were filled with blue phosphate of iron.

26. Peat-bogs.—Before proceeding to the next subject, I will advert to those extensive accumulations of vegetable matter called Peat-bogs. These are morasses, covered with successive layers or beds of mosses, reeds, equiseta, rushes, and other plants that affect a marshy soil; and in particular of a kind of moss, the *sphagnum palustre*, which frequently forms a large proportion of the entire mass. The beds of peat are annually augmented by the peculiar mode of increase of the moss, which throws up a succession of shoots to the surface, while the parent plants decay, and add a new layer of soil.

The peat-bogs of Ireland are of great extent: one of the mosses on the banks of the Shannon is between two and three miles in breadth, and fifty in length. Sir C. Lyell remarks, that most of the peat-mosses of the North of Europe occupy the areas of ancient forests of oak and pine; and that the fall of trees from the effect of storms, or natural decay, by obstructing the draining of a district, and thus giving rise to a marsh, is the origin of most of these deposits; mosses and other marsh-plants spring up, and soon overwhelm and bury the prostrate trees; hence the occurrence of trunks and branches of oaks, firs, &c., with their fruits. De Luc states, that the sites of many of the aboriginal forests on the continent * are now covered by mosses and fens, and that many of these changes are attributable to the destruction of the woods by the Romans.

A remarkable circumstance relating to peat-bogs must not be omitted, namely, the occasional occurrence of the bodies of men and animals, in a high state of preservation, at a great

* See Hochstetter on the Peat-bogs of Bohemia, Annals Nat. Hist. 2nd Ser. vol. xvi. p. 378.

depth. In some instances the bodies are converted into a fatty substance resembling spermaceti, and which is called *adipocire*.

27. COAL IN PEAT.—A fact of considerable geological interest is the occurrence of coal in peat-bogs; since it proves that the conversion of vegetable matter into a mineral, the origin of which, but a few years since, was deemed questionable, takes place at the present time, when circumstances are favourable for the production of the bituminous fermentation. In Limerick, in the district of Maine, one of the States of North America, there are peat-bogs of considerable extent, in which a substance exactly similar to *cannel coal* is found at the depth of three or four feet from the surface amidst the remains of rotten logs of wood and *beaver-sticks:* the peat is twenty feet thick, and rests upon white sand. This coal was discovered on digging a ditch to drain a portion of the bog, for the purpose of obtaining peat for manure.* The substance is a true bituminous coal, containing more bitumen than is found in any other variety.† Polished sections of the compact masses exhibit the peculiar structure of coniferous trees, and prove that the coal was derived from a species allied to the American fir. It has probably been formed by the chemical changes supervening upon fir-balsam, during its long immersion in the humid peat; the circumstances under which it was placed being most favourable for that process to take place by which, as we shall show hereafter (see *Lecture* VI.), vegetable matter is converted into coal. In the Chatham Islands, Dr. Dieffenbach observed a bed of peat in which were layers closely resembling coal, and possessing a lustrous appearance and conchoidal fracture; while in other parts of the same layers the transition to true peat was evident.

* Dr. Jackson, on the Geology of Maine.

† An analysis of 100 grains gave the following results:—*Bitumen*, 72; *Carbon*, 21; *Oxide of Iron*, 4; *Silica*, 1; *Oxide of Manganese*, 2 = 100.

28. Subterranean forests.—Independently of the trees imbedded in peat-bogs and morasses, there are also found entire forests buried deeply in the soil; the trees having their roots, trunks, branches, fruits, and even leaves, more or less perfectly preserved. Numerous accumulations of this kind have been discovered on the coasts of England, occupying low alluvial plains, that are still subject to periodical inundations.* The trees are chiefly of the oak, hazel, fir, birch, yew, willow, and ash; in short, almost every kind that is indigenous to this island occasionally occurs. The trunks, branches, &c. are dyed throughout of a deep ebony colour by iron; and the wood is firm and heavy, and occasionally fit for domestic use; in Yorkshire and elsewhere, timber of this kind is sometimes employed in the construction of houses.

29. Geological effects of the ocean.—While the mountains, valleys, and plains of the interior of the country are undergoing slow but perpetual destruction by the combined effects of atmospheric agency and of running water, the coasts, cliffs, and shores are exposed to destruction from the action of the waves and the encroachments of the sea. When the land presents a high and rocky coast, the waves, by their incessant action, undermine the cliffs, which at length fall down and cover the shore with their ruins. The softer parts of the strata, as the chalk, limestone, marl, clay, &c., are rapidly disintegrated and washed away; while the more solid materials are broken and rounded, by the continual agitation of the water, and give rise to those accumulations of shingle and sand which skirt the base of the sea-cliffs, and serve, in some situations, to protect the land from further encroachments. But, when the cliffs are entirely composed of soft substances, their destruction is very rapid, unless artificial means be employed for their protection; these, however, in many instances are wholly ineffectual.

* See Illustrations of the Geology of Sussex, p. 288.

The encroachments of the ocean upon the land, effected by this agency, often give rise to sudden and extensive inundations, and the destruction of whole tracts of country. Along the Sussex coast the inroads of the sea have been noticed in the earliest historical records; and the site of the ancient town of Brighton has been entirely swept away, the sands and the waves now occupying the spot where the first settlers on these shores fixed their habitations.* On low and sandy coasts, the waves drive the loose and lighter materials towards the land; and the drifted sand, becoming dry at the reflux of the tide, is carried by the wind inland, and in some situations is accumulated in such quantities as to form ranges of hills, which in their progress overwhelm fertile tracts, and ingulf churches and even entire villages. These sand-banks (dunes or downs), loose and fluctuating as they are in their first stage of advancement, become under certain circumstances stationary, and are then converted into solid stone, by a process which we shall presently explain.

30. THE BED OF THE OCEAN.—But the production of beach, gravel, and sand on the shores, and the drifting of sand inland, are effects far less important than those which are going on in the depths of the ocean. In the tranquil bed of the sea, the finer materials, that were held in chemical or mechanical suspension by the waters, are precipated and deposited, enveloping and imbedding shells, corals, fishes, &c., together with the remains of such terrestrial animals and vegetables as may have been floated down by the streams and rivers. And, in the beautiful language of Mrs Hemans,—

> "The depths have more! What wealth untold
> Far down and shining through their stillness lies!

* In my "Fossils of the South Downs," and "Geology of the South-East of England," will be found some interesting historical notices of the destruction of the Sussex coast by the inroads of the sea.

They have the starry gems, the burning gold,
Won from a thousand royal argosies!
"Yet more—the depths have more! Their waves have rolled
Above the cities of a world gone by—
Sand hath filled up the palaces of old,—
Sea-weed o'ergrown the halls of revelry.
"To them the love of woman hath gone down,
Dark flow their tides o'er manhood's noble head,
O'er youth's bright locks, and beauty's flowery crown."—

Yes! in these modern deposits, the remains of man, and of his works, must of necessity be continually ingulfed, together with those of the animals which are his contemporaries.

Of the nature of the present bed of the ocean, we can of course know but little from actual observation.* Soundings, however, have thrown light upon the deposits now forming in those depths which are accessible to this mode of investigation, and shown that in many parts immense accumulations of shells and corals, intermixed with sand, gravel, and mud, are going on. Donati ascertained the existence of a compact bed of shell, 100 feet in thickness, at the bottom of the Adriatic, which in some parts was converted into marble. In the British Channel, extensive banks of sand, imbedding shells, crustacea, &c., are in the progress of formation. This specimen, which was dredged up a few miles off Brighton, is an aggregation of sand with recent marine shells, oysters, mussels, limpets, cockles, &c., and minute bryozoa; † and this example, from the coast of the Isle of Sheppey, consists entirely of cockles (*Cardium edule*), held together by conglomerated sand.‡

* It has been supposed, that, probably for a large portion of its extent, the depth of the ocean is three times greater than the height of the highest mountains; and therefore that large spaces may be found to give soundings of nearly eight miles' depth,—about three times the average height of the Himalayan Mountains.

† Medals of Creation, 2nd edit. vol. i. p. 385, *lign.* 123.

‡ Ibid. p. 386, *lign.* 124.

In bays and creeks bounded by granitic rocks, the sea-bottom is composed of micaceous and quartzose sand, consolidated into what may be termed regenerated granite. Off Cape Frio, on the Brazilian coast, solid masses of this kind are formed in a few months, and completely enveloped the dollars and other treasures from the wreck of a vessel, the *Thetis*, to recover which an exploration by the diving-bell was successfully undertaken.*

31. EFFECTS OF CURRENTS.—The distribution over the bottom of the sea of the detritus brought down by rivers and streams, and of the materials worn away by the action of the waves on the shores, is principally effected by the influence of currents, which, from their regularity, permanency, and extent, may be considered as the rivers of the ocean. To this agency I can but briefly allude, and shall restrict my remarks to the Gulf-stream, which is the great current that transports the waters, and the temperature of the tropical regions, into the climates of the north. From the mouth of the Red Sea a current, about fifty leagues in breadth, sets continually towards the south-west; doubling the Cape of Good Hope, it assumes a north-west direction, and in the parallel of St. Helena its breadth exceeds 1000 miles; then taking a direction nearly east, it meets in the parallel of 3° north, along the northern coast of Africa, with a stream from the north; entering the Gulf of Florida, the united currents are reflected and form the Gulf-stream, which, passing along the coast of North America, stretches across the Atlantic to the British Isles. At the parallel of 38°, nearly 1000 miles from the Straits of Bahama, the water of the stream is ten degrees warmer than the air. The course of the Gulf-stream is so fixed and regular, that nuts and plants from the West Indies are annually drifted to the western islands of Scotland. The mast of a man-of-war,

* See Commander T. Dickinson's Narrative, Royal Society Proceedings, 1833, p. 271.

burnt at Jamaica, was driven ashore several months afterwards on the Hebrides, "after performing a voyage of more than 4000 miles under the direction of a current, which, in the midst of the ocean, maintains its course as steadily as a river upon the land." * The quantity and variety of detritus transported by such currents must be immense, and we therefore need not wonder at frequently finding the productions of different climates associated together in a fossil state.

32. Icebergs and glaciers.—From the consideration of the dynamical powers of water as a fluid, we pass to the examination of its effects when consolidated by congelation. The character of the regions of eternal ice in the Arctic circle,—the floating islands and mountain-ranges composed of rock-ice, which everywhere threaten with impending destruction the intrepid mariners who penetrate the desolate polar seas,—the removal and transport of immense masses of rocks and boulders by drifting ice-floes, and the distribution of these materials in the bed of the ocean, or on the land, as the congealed water gradually melts when it approaches a milder climate,—are phenomena so familiar to the English reader, from the graphic pictures and heart-stirring narratives, which have emanated from our naval officers and others engaged in the arduous service of the voyages of discovery undertaken during the present century, that it will not be necessary to dwell upon the subject.

Glaciers are sheets of ice, which are formed upon the tops and in the clefts and valleys of mountains that attain such an elevation as to be within the regions of eternal snow. They are not inaptly termed, by that most charming of all philosophical travellers, Mr. Darwin, gigantic icicles. The lowest limit to which glaciers extend depends, of course, on the height of the line of perpetual congelation, which varies

* Playfair's Works, edition 1822; vol. i. p. 414.

in different latitudes, and is also modified by the configuration of the land. In the Alps the traveller enters the region of eternal snow at an elevation of from 3000 to 7000 feet; while in South America, under the equator, the height of the snow-line is equal to that of the submit of Mont Blanc. In the Alps there are vast table-lands, of from 100 to 300 square miles, composed of solid snow and ice, from which descend enormous masses, slowly gliding towards the lower regions, and bearing with them innumerable fragments of rock. As soon as these glaciers reach the lowest limit of perpetual congelation, they melt, and the fragments of rock which they contain are deposited, and form mounds and ridges of stones of all sizes, which are called *moraines;* these remain after all vestiges of the agent which produced them have disappeared. The difference in the character of the materials brought down by torrents and by glaciers is very manifest: for the former give rise to beds of gravel; the latter to ridges or heaps of boulders. The movement of the glacier from the mountain-top arises mainly from the pressure of the ice-mass above, and from the softened state of the layer of ice in contact with the surface of the earth on which it rests; for the beautiful experiments of Professor Forbes have shown that ice moves upon the principle of a tenacious or viscous fluid; that is, by gravitation on an inclined surface. The rocks forming the bases of the glaciers, and the sides of the valleys they have traversed, are more or less polished and grooved, from the passage of angular masses of rock impacted in the moving ice: the grooves being in the direction of the movement of the glacier.*

From careful observations on these appearances, M. Agassiz has established characters by which, in countries where

* See "Etudes sur les Glaciers," by L. Agassiz; Neuchatel, 1840; and the Memoirs of Prof. Forbes (in Phil. Trans.), on the same subject; also Forbes's Travels in the Alps and in Norway; and Tyndall's Lecture, Roy. Instit. Jan. 23, 1857.

the hills are at the present time far below the snow-line, evidence of former glaciers of great extent has been obtained. Many indications of ancient glaciers occur in England and Scotland: the accumulations of drifted materials, containing large angular blocks, and disposed in long banks and ridges, as well as grooves and scratches on the surface of certain rocks forming the sides of valleys and slopes of hills, are regarded by some geologists as unequivocal proofs of a great extent of glaciers in these islands at a comparatively recent period: and the drift, boulders, and superficial alluvial debris are attributed, in a great measure, to the agency of either icebergs, coast-ice, or glaciers. But the sweeping conclusion of M. Agassiz, and others, that the whole of Europe was once covered with ice, should be received with much hesitation.

The former existence of glaciers in some parts of Great Britain, perhaps accompanied with a lower climatorial temperature than now prevails, appears to me the extent to which, in the present state of our knowledge, the glacial theory can be admitted as a *vera causa* in our attempts to interpret the origin of the drift of the British islands. It may, however, be well to state, that, if an elevation of the European continent to the amount of but 2000 feet were to take place, a great part of its surface would be covered with glaciers and perpetual snow, and would cease to be habitable.

33. INCRUSTING SPRINGS.—The phenomena hitherto considered are referable to the mechanical action of water; and the effect has been disintegration and destruction, in the first instance, and, in the second, the accumulation of sediments in water-courses, and their transport into the bed of the sea. We must now refer to an operation of a totally different character—the power possessed by streams, as clear and sparkling as poet ever feigned or sung, of consolidating loose materials, of converting porous strata into solid stone, and of filling up their own channels by the deposition of calcareous matter.

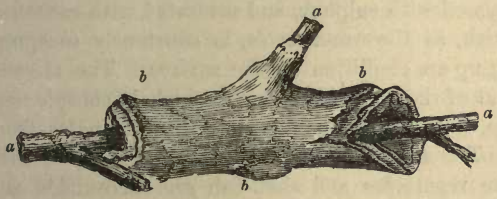
That most fresh water holds a certain proportion of carbonate of lime * in solution, is well known; and also that changes of temperature, and certain other causes, will occasion the calcareous earth to be in part or wholly precipitated. The *fur*, as it is called, that lines a boiler which has been long in use, affords a familiar illustration of this fact. At the temperature of 60°, lime is soluble in 700 times its weight of water; and, if to the solution a small portion of carbonic acid be added, carbonate of lime is formed, and precipitated in an insoluble state. If, however the carbonic acid be in such quantity as to supersaturate, the lime, it is again rendered soluble in water; and it is thus that carbonate of lime, held in solution by an excess of carbonic acid, not in actual combination with the lime, but contained in the water and acting as a menstruum, is commonly found in all waters. An absorption of carbonic acid, or a loss of that portion which exists in excess, will therefore occasion the calcareous earth to be set free, and precipitated on any substances in the water, such as stones, twigs, and leaves of trees, &c. Some springs contain so large a portion of calcareous earth when they first issue from the rocks, and so speedily throw it down in their course, that advantage has been taken of the circumstance to obtain incrustations of various objects, as leaves, branches, baskets, nests with eggs, and even old wigs. The incrusting springs of Matlock and other places in Derbyshire are celebrated for such productions.† The substance deposited is termed tufa, or travertine; and in Italy and many other countries, it constitutes extensive beds of concretionary limestone,

* *Carbonate of lime* consists of lime in combination with carbonic acid gas, which is a most abundant natural product. This gas is irrespirable, and, when pure, will immediately suffocate an animal immersed in it, and extinguish flame.

† An account of the incrusting springs at Matlock is given in "Medals of Creation," vol. ii. p. 872.

which is often of a crystalline structure. The Cyclopean walls and temples of Pæstum are formed of travertine. At the baths of San Filippo, in Tuscany, where the waters are highly charged with tufa, this property is applied to a very ingenious purpose. The stream is directed against moulds of medallions and other bas-reliefs, and beautiful casts are thus obtained.

34. INCRUSTATIONS.—As specimens of this kind are commonly, but erroneously, termed petrifactions, it will be necessary to explain their real nature. We have before us several incrustations from various places: baskets of shells, and nests with eggs, from Derbyshire; a bird from Knaresborough, in Yorkshire; and twigs and branches partially incrusted, from Ireland, Russia, &c.



LIGN. 8.—A TWIG INCRUSTED WITH TUFA.

a, *a*, *a*, Extremities of the twig unchanged: *b*, *b*, *b*, the tufaceous crust.

I need scarcely observe, that, on breaking such specimens, we find the enclosed substances to have undergone no change but that of decay. In this incrustation (*Lign.* 8) the twig, which is exposed in several places, is not permeated by stony matter, but is withered and brittle. Now, a true *petrifaction* is altogether of a different nature, the substance being more or less completely mineralized; if we break it, we find that every part of its structure has undergone a change. Wood, for instance, is often entirely transmuted into flint or chalcedony, and may be cut so thin, that with a powerful lens the ramifications of the vessels and the structure of the

tissues may be seen, and from their form and disposition we may determine the particular kind of tree to which the specimen belonged, although it may have been enshrined in the stone for ages. When bone is petrified, the same phenomena are observable; the most delicate parts of the internal structure are preserved, and all the cells are filled up with calcareous spar, which is oftentimes of a different colour from that of the walls of the cells, and thus a natural anatomical preparation of great beauty and interest is formed.

35. LAKE OF THE SOLFATARA.—One of the most celebrated travertine-springs is the lake of the Solfatara, which lies in the Campagna between Rome and Tivoli, and is fed by a stream of thermal water that flows into it from a neighbouring pool. The water is of a high temperature, strongly impregnated with sulphur, and saturated with carbonic acid gas, which, as the water cools, is constantly escaping, and keeping up an ebullition on the surface. The stream that flows out of the lake fills a canal, which is conspicuous at a distance, from the line of vapour that emanates from the water. The formation of travertine is so rapid, that not only the vegetables and shell-fish are surrounded and destroyed by the calcareous deposit, but insects also are frequently incrusted. In the beautiful specimens of travertine before us from the Solfatara, vegetable impressions are distinctly seen; the cavities in these masses have been produced by the decomposition of the vegetable matter.*

A considerable number of the edifices of both ancient and modern Rome are constructed of travertine obtained from the quarries of Ponte Luccano, which has clearly originated from a lake of this nature. Pæstum is also built of calcareous tufa, derived from similar deposits. The waters of these lakes, according to Sir Humphry Davy,† have their rise at

* See Appendix C.

† Consolations in Travel: or, the Last Days of a Philosopher.

the foot of the Apennines, and hold in solution carbonic acid, which has dissolved a portion of the calcareous rocks through which it has passed; the carbonic acid is dissipated by the atmosphere, and the marble, slowly precipitated, assumes a crystalline form, and produces coherent stone. The acid originates in the action of volcanic fires on the calcareous rocks of which the Apennines are composed, and carbonic acid, being thus evolved, rises to the source of the springs, and gives them their impregnation, and enables them to dissolve a large quantity of calcareous matter.

36. MARBLE OF TABREEZ.—In Persia, a beautiful transparent limestone, called Tabreez marble, is formed by deposition from a celebrated spring near Maragha, where the whole process of its formation may be seen. In one part the water is clear; in another dark, muddy, and stagnant; in a third it is very thick, and almost black; while in the last stage it is of a snowy whiteness. The petrifying pools look like frozen water; a stone thrown on them breaks the crust, and the water exudes through the opening; and in some states the process has proceeded so far as to admit of walking on the surface of the lake. A section of the stony mass resembles an accumulation of sheets of paper, being finely laminated; and such is the tendency of this water to solidify, that the very bubbles on its surface become hard, as if they had been suddenly arrested, and metamorphosed into a stone.*

37. STALACTITES AND CAVERNS.—By the infiltration of water through limestone-rocks into fissures and cavities, sparry concretions are produced on the roofs, sides, and floors of caverns. The concretionary masses which are dependent from the roof like icicles are called *stalactites;* those which form on the floor, from the droppings of the water, are termed *stalagmites;* and when, as frequently happens, the two unite, a singularly picturesque effect is produced;

* Morier's Travels.

the caves appearing as if supported by pillars of great beauty and variety.* Sometimes a linear fissure in the roof, by the direction it gives to the dropping of the lapidifying water, forms a perfectly transparent curtain or partition. A remarkable instance of this kind occurs in a cavern in North America, called Weyer's Cave, which is situated in the limestone-range of the Blue Mountains.† There are also many caverns in England celebrated for the variety and beauty of their sparry ornaments; those of Derbyshire are well known.

The Grotto of Antiparos in the Grecian Archipelago, not far from Paros, has long been celebrated. The sides and roof of its principal cavity are covered with immense incrustations of calcareous spar, which form either stalactites, depending from above, or irregular pillars rising from the floor. Several perfect columns reaching to the ceiling have been formed, and others are still in progress, by the union of the stalactite from above with the stalagmite below. These, being composed of matter slowly deposited, have assumed the most fantastic shapes; while the pure, white, and glittering spar beautifully catches and reflects the light of the torches of the visitors to this subterranean palace, in a manner which causes all astonishment to cease at the romantic tales told of the place—of its caves of diamonds and of its ruby walls; the simple truth, when deprived of all exaggeration, being sufficient to excite admiration and awe.‡

The specimens before us will serve to illustrate these remarks: these long stony icicles are from the Isle of Portland; and these minute straws of spar are from an archway near the Chain Pier, Brighton, and have been formed by the infiltration of rain through the superincumbent bed of calcareous

* Appendix D. † Appendix E.

‡ A good idea of the celebrated Cave of Adelsberg described by Sir H. Davy as the habitation of the *Proteus*, and of the Derbyshire caverns, may be obtained by an inspection of the model in the Colosseum in the Regent's Park; and also of that in the Crystal Palace Gardens.

rock. This mass of pebbles, held together by calc-spar, and containing bones and teeth of some ruminant, is from the cliffs at Kemp Town, and shows, that in periods very remote, the same process was in action along the Sussex shores. These beautiful slabs of marble are portions of stalagmites, from St. Michael's Cave, Gibraltar; and this large conical mass, which has been cut through and polished to show its structure, was dug up on the summit of Alfriston Hill, in Sussex, and must have been formed in some fissure or cavern in the chalk, of which no traces now remain.

38. CONSOLIDATION OF LOOSE SAND, &c.—The changes effected by this process in strata composed of loose materials are of still greater importance; for by an infiltration of crystallized carbonate of lime sand is converted into sand-stone, —fragments of soft chalk are transmuted into a solid rock, as in the Coombe-rock of Brighton,—and accumulations of beach and gravel into a hard conglomerate, as in this example of the ancient shingle-bed of the cliffs at Rottingdean;—shells, into a building-stone, as in this mass from Florida,—and the detritus of shells and corals, into limestone, as in these specimens from Bermuda. By this agency, the bones of animals are permeated with calcareous spar, and their medullary cavities lined with crystals of carbonate of lime: and clay, which has cracked by drying, has its fissures filled up, and becomes consolidated into those curious masses, called *septaria*, which, when polished, form the beautiful table-slabs for which Weymouth is celebrated.

39. DESTRUCTION OF ROCKS BY CARBONIC ACID GAS.—Although, in the instances above cited, water, by its combination with carbonic acid, occasions the solidification of loose and porous beds of detritus, yet the effect of this gas on certain rocks is that of disintegration; for, by its solvent influence on the felspar, granite itself is reduced to a friable state, the quartz and mica, which with felspar constitute that rock, being set at liberty. The disintegration of granite

is a striking feature throughout extensive districts in Auvergne, especially in the neighbourhood of Clermont. In the ancient shingle of the cliffs at Kemp Town, near Brighton, blocks of granite occur which may be crumbled to pieces between the fingers. I have already shown you masses of pebbles held together by calcareous spar, from the same locality; we have, therefore, examples, in that ancient shingle-bed, both of the conservative and the disintegrating effects of carbonic acid,—cementing the loose beach into solid blocks by calcareous depositions, and, when in a gaseous state, or combined with water, dissolving the granite by its action on the felspar.

40. CARBONIC ACID GAS IN CAVES.—The escape of carbonic acid gas through fissures into mines, wells, and caverns is of frequent occurrence; and, as the specific gravity of this gas is greater than that of atmospheric air, it forms an invisible pool at the bottom of these cavities, and its presence is seldom suspected until shown by its deleterious effects; hence fatal accidents often happen to well-diggers and excavators from this cause;* it is called choke-damp by miners.

The *Grotto del Cane*, near Puzzuoli, four leagues from Naples, has for centuries been celebrated on account of the constant evolution, from fissures in the rock, of carbonic acid gas in combination with much aqueous vapour, which is condensed by the coldness of the external atmosphere. The floor of the cavern being lower than the entrance, the gas is spread over the bottom like a pool of water, and the upper part is free from any noxious vapour; the suffocating effect of the carbonic acid is, therefore, not felt by any creature whose organs of respiration are above the level of this mephitic lake; but if a dog, or other small animal, enter the cave, it instantly falls senseless, and would expire if not speedily removed: the name of the cave is derived from the

* A few pounds of quicklime thrown into a well quickly absorbs the carbonic acid gas.

experiment being often made on dogs, for the amusement of visitors.* It is impossible to fire a pistol at the bottom of the cavern; for, though gunpowder may be exploded even in carbonic acid by the application of a heat sufficient to decompose the nitre, and consequently to envelope the mass in an atmosphere of oxygen gas, yet the influence of a mere spark from steel produces too slight an augmentation of temperature for this purpose.†

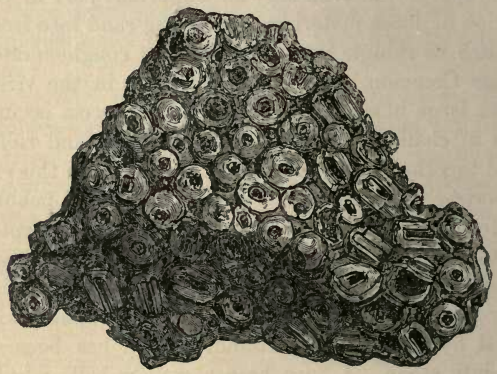
41. Consolidation by iron.—Water charged with a large proportion of iron acts an important part in the consolidation of loose materials, converting sand into ironstone, and beach or shingle into a ferruginous conglomerate. On Clapham Common, and in other places in the vicinity of London, large blocks of a very compact breccia occur, being masses of chalk-flints, more or less broken and rolled, cemented together by an infiltration of iron. In this example of a horse-shoe firmly impacted in a mass of pebbles and sand, from the sea-beach at Eastbourn, the cement which binds the mass is derived from the iron. Nails are frequently found in the centre of a nodule of hard sandstone formed by this process; the nail having supplied the water with the material by which the surrounding sand has become concreted into stone. I have here a cannon-ball imbedded in the centre of a nodule of iron-stone, in which are several oyster-shells: this specimen was dredged up off the Sussex coast, and has evidently been consolidated by the partial oxidation of the iron.

In this mass of breccia, which has been produced by a like process, are two silver pennies of Edward I.; it was found in 1832, at a depth of ten feet in the bed of the river Dove, in Derbyshire. The coins are presumed to be part of the treasures contained in the military chest of the Earl of Lancaster, which was lost in this stream in 1322; the soldiers,

* See Sandys' Travels; London, 1637.

† Daubeny on Volcanos.

being alarmed by a sudden panic, threw the chest with all its contents into the Dove, and it was never recovered. This specimen, with many others, was dug up in deepening the bed of the river; more than five centuries have, therefore, elapsed since its immersion.* A particular account of this discovery is given in the Penny Magazine for November, 1834; many thousand silver coins, comprising a great variety of the English, Irish, and Scotch coinage of the 13th and 14th centuries, were found imbedded in a hard conglomerate.



LIGN. 9.—FERRUGINOUS CONGLOMERATE, COMPOSED OF BEADS AND KNIFE-BLADES, FROM A STRANDED SHIP, OFF HASTINGS.

This curious specimen (*Lign.* 9), for which I am indebted to my friend, George Grantham, Esq., of Barcombe Place, Sussex, was obtained from a Dutch vessel that was stranded off Hastings a century ago, and became imbedded in silt and sand. It is a conglomerate of glass beads, knives, and sand; the cementing material having been derived from the oxidation of the blades. From the bed of the Thames, large masses of a firm conglomerate are occasionally dredged up, in which Roman coins and fragments of pottery are imbed-

* See the Vignette of the Title-page.

ded; the stone being formed of sand and clay solidified by ferruginous infiltration.

These specimens of oxide of iron were dug up in a marshy soil, near Bolney, in Sussex, and are of the same nature as the substance called bog-iron ore, which so frequently occurs in peat. Specimens of bog-iron are not uncommon in the superficial loam and gravel of the south-east of England. The ebony colour of the bog-wood from Ireland, which we have already noticed, has been derived from an impregnation of iron.

The consolidation of sand, gravel, and other detritus by this agency is taking place everywhere; on the shores of the Mediterranean; on the coasts of the West India Islands, and of the Isle of Ascension; and on the borders of the United States; thus, the remains of man at Guadaloupe—of turtles, in the Isle of Ascension—of recent shells and bones of ruminants, at Nice—of ancient pottery in Greece—and of animal and vegetable substances, in our own country, have become imbedded and preserved.

I now proceed to notice a few instances of these simple but important operations, by which much of the solid crust of the globe is continually being renewed.

42. RECENT LIMESTONE OF THE BERMUDAS.—The shores of the Bermuda Islands* afford interesting examples of this class of deposits in different states of consolidation. The sea surrounding the Bermudas abounds in corals and shells; and from the action of the waves on the reefs and on the dead shells, the water becomes loaded with calcareous matter. Much of the detritus is transported to a distance, and subsides in the depths of the ocean, imbedding the remains of animals and vegetables; but a great portion is borne by the waves towards the shores, and cast up on the strand in the state of fine earth and sand. This detritus is blown

* See Nelson's Memoir on the Bermudas, *Geol. Trans.*, 2 ser. vol. v p. 103; and on the Bahamas, *Quart. Geol. Journ.*, vol. ix. p. 200.

inland by the winds, and is soon consolidated by the percolation of water and the infiltration of crystallized carbonate of lime; a fine white calcareous stone is thus formed, which in some localities forms the drip-stone or filter-stone, and sometimes is sufficiently compact for building. In this rock are numerous shells and corals, of species which inhabit the neighbouring seas; in some instances the large mottled turbo, so well known to collectors both in its natural and polished state, with all its colours preserved, is imbedded in a pure white limestone. In many specimens the colours are faded, and the shells very much in the state of those found in the tertiary strata at Grignon; in others the shelly matter is wanting, but the hard stone retains the forms and markings of the originals. The corals are imbedded in a similar manner; and masses occur in the limestone so like the fossil corals of the oolite of this country, that it requires an experienced eye to detect their real nature.

In a suite of specimens, showing the transition from loose sand to solid rock, we have—

1. Broken shells and corals, retaining their colours.
2. Similar materials, more comminuted and completely bleached.
3. An aggregation of fine sand and white earth, broken shells, and corals.
4. Friable limestone, resembling soft chalk, and composed of comminuted corals, corallines, &c.
5. Hard limestone, of similar materials.
6. Compact limestone, enveloping shells and pebbles.
7. A fine indurated limestone, so hard as to be with difficulty broken by the hammer, enclosing a few shells and corals: this stone is employed for building. *

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* On this bare calcareous rock the coffee-plant finds sufficient support, and is seen in many places growing luxuriantly, its stems shooting out from between the crevices of the stone. In the botanic gardens at Kew are several coffee-plants from Bermuda, growing on blocks of this rock.

The Bahamas, and others of the West Indian Islands, mainly consist of similar coral-deposits. Some of the indurated coral-sands occasionally contain eggs of alligators and of turtles.

In the lakes of Forfarshire, in Scotland,* fresh-water limestone, containing recent shells and aquatic plants, is in progress of formation. In the specimens before us, which were collected by Sir C. Lyell, are various species of fresh-water shells, and masses of that common fresh-water plant, the *Chara medicaginula*, beautifully preserved; even the minute seed-vessels of the chara are converted into stone, in precisely the same manner as those in the ancient fresh-water tertiary limestones.† Here then is an example of the formation of a modern lacustrine rock; while, in the recent limestones of Bermuda, we have proof that the sea is at this time forming shelly and coralline rocks, analogous to many of the ancient secondary strata.

43. FOSSIL HUMAN SKELETONS.—Similar aggregations are in progress along the shores of the whole West Indian

LIGN. 10.—SECTION OF THE CLIFFS AT GUADALOUPE.
A, Ancient rocks; B, recent limestone, in which human skeletons are found imbedded.

Archipelago; and in St. Domingo they have greatly extended the plain of Cayes, where accumulations of con-

* Geological Transactions, 2nd series, vol. i. p. 73.

† See Geological Excursions round the Isle of Wight, p. 77: Medals of Creation, vol. i. p. 195.

glomerate occur, and in which, at the depth of twenty feet, fragments of ancient pottery have been discovered. On the north-east coast of the main-land of Guadaloupe, a bed of recent limestone forms a sloping bank from the steep cliffs of the island to the sea, and is nearly all submerged at high tides. This modern rock is composed of consolidated sand and comminuted shells and corals of species now inhabiting the adjacent seas: land-shells, fragments of pottery, stone arrow-heads, carved stone and wooden ornaments, and human skeletons, are occasionally found imbedded in it. This circumstance, being the first known undoubted example of the occurrence of human bones in solid limestone, excited great attention; and the fact, simple and self-evident as is its explanation, was made the foundation of many vague and absurd hypotheses.

In most instances the bones are dispersed; but a large slab of rock, in which a considerable portion of the skeleton of a female is imbedded, is preserved in the British Museum, and has been described by Mr. König, in a highly interesting memoir, published in the Philosophical Transactions of 1814. The annexed representation (*Lign.* 11) will convey an idea of this celebrated relic, which was detached from the rock at the Mole, near Point-a-Pitre.

In this specimen the skull is wanting, but the spinal column, many of the ribs, and the bones of the left arm and hand, of the pelvis, and of the thighs and legs, remain. The bones still contain some animal matter and the whole of their phosphate of lime. It is remarkable, that the fragments of the skull of this very specimen have recently been purchased, for the museum at South Carolina, of a French naturalist, who brought them from Guadaloupe; and they have been described by Professor Moultrie, of the Medical College of that State. These relics consist of portions of the temporal, parietal, frontal, sphenoidal, and inferior maxillary bones of the right side of the skull. An entire skele-

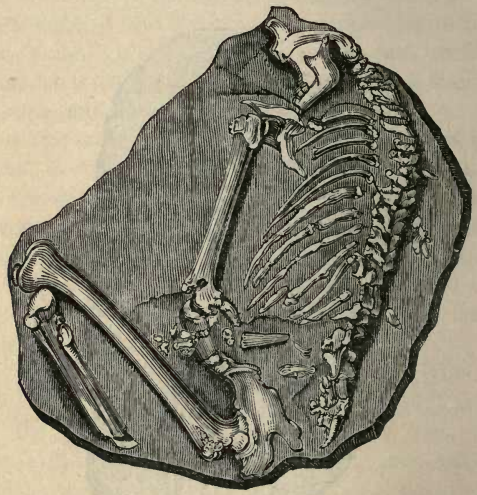
ton was also discovered in the usual position of burial; and another, in a sitting posture, in a softer sandstone. The bodies, thus differently situated, may have belonged to distinct tribes. General Ernouf, who carefully investigated this interesting deposit, conjectured that the presence of the bones might be explained by the circumstance of a battle, and the massacre of a tribe of Gallibis by the Caribs, which took place near this spot, about 120 years ago; for, as the bodies of the slain were interred on the sea-shore, their skeletons may have subsequently been covered by

LIGN. 11.—FOSSIL HUMAN SKELETON, FROM GUADALOUPE.
In the British Museum; size of the original, 4 feet 2 inches by 2 feet.

sand-drift, which has since consolidated into limestone. Dr. Moultrie, however, from a rigorous examination and comparison of the bones of the skull in his possession, is of opinion, that the specimen in the British Museum did not

belong to an individual of the Carib, but to one of the Peruvian race, or of a tribe possessing a similar craniological development.

In another skeleton from Guadaloupe, now in the museum of the *Jardin des Plantes*, and represented in the last edition of Cuvier's *Théorie de la Terre*, the figure is bent, the spine forms an arc, and the thighs are drawn up as if the individual were in a sitting posture; a portion of the upper jaw, and the left half of the lower with several teeth, nearly the whole of one side of the trunk and pelvis, and a



LIGN. 12.—HUMAN SKELETON FROM GUADALOUPE.
In the Museum at Paris.

considerable portion of the upper and lower left extremities, are preserved (*Lign.* 12). The stone encloses terrestrial and marine shells; it is evident that the former have been drifted by streams from the interior, and the latter deposited by the sea. In the bed from which this block was ex-

tracted, were found teeth of the *Caiman* (a species of crocodile), stone hatchets, and a piece of wood, having rudely sculptured on one side a mask, and on the other the figure of an enormous frog; it is of guaiacum, but has become extremely hard, and as black as jet.*

Human skeletens have also been found in solid calcareous tufa near Santa in Peru. Bones, belonging, it is computed, to some scores of individuals, were discovered imbedded in travertine, containing fragments of marine shells which still possess colour. The bed of stone is covered by a deep vegetable soil, and forms the face of a hill crowned with brushwood and large trees, on the side of the river Santa.†

44. Isle of Ascension. — In the Isle of Ascension, which is a volcanic cone in the midst of the Atlantic, and appears to have been a dome of trachytic rocks, subsequently affording vent to lava-currents, a recent deposit of conglomerate is going on. Its coasts are flanked by accumulations of concreted sand with comminuted shells, corals, echini, and fragments of lava. The specimens before us are portions of this modern rock in various states of consolidation; they are composed of corals, which still retain their colour, of shells, more or less broken, and of sand of similar materials; they also contain pebbles of trachytic and glassy lava. The shores of this island are a favourite resort of turtles, which repair thither in immense numbers, and deposit their eggs in the loose sand: the rapid conversion of the coarse calcareous banks into solid stone occasions the frequent imbedding and preservation of the eggs; and there

* In former editions of this work a notice was given of some supposed imprints of human feet on limestone, figured and described in an early volume of the American Journal of Science. These markings have since been carefully examined by Dr. Dale Owen, of New Harmony, and prove to have been sculptured by the Aborigines.

† American Philosophical Transactions for 1828, p. 283.

are specimens in the cabinet of the Geological Society, in which the bones of young turtles, just on the point of being hatched, are preserved. The conglomerate of the Isle of Ascension is, as you may observe, principally composed of corals. Here we have another example of a rock formed of the calcareous skeletons of those wonderful forms of organic existence; but it is not my intention in this place to dwell on the geological changes produced by zoophytes in the formation of coral-reefs, &c., as the examination of the recent and fossil corals will form the subject of a subsequent Lecture.

45. DRIFTED SAND.—We have already alluded to the encroachments on the land by the drifting of sand-banks, thrown up beyond the reach of the tide, and driven by the winds inland; thus effecting the desolation of whole regions by their slow but certain progress. Egypt instantly presents herself to the imagination, with her stupendous pyramids, the sepulchres of a mighty race of monarchs, and the wonder of the world—her temples and palaces, once so splendid and massive as to bid defiance to the ravages of time—her plains and valleys, formerly teeming with abundance and supporting a numerous population—now stripped of her ancient glories, her fairest regions depopulated, and converted into arid wastes,—her cities overwhelmed and prostrate in the dust,—and the colossal monuments of her kings and the temples of her gods half buried beneath the sands of the Desert!

The drifting of the sands of the Libyan desert by the westerly winds, observes M. De Luc, has left no lands capable of cultivation on those parts of the western bank of the Nile which are not sheltered by mountains; while in Upper Egypt, whole districts are covered by moveable sands, and here and there may be seen the summits of temples and the ruins of cities which they have overwhelmed. "Nothing can be more melancholy," says Denon, "than to walk over vil-

lages swallowed up by the sand of the Desert, to trample under foot their roofs and minarets, and to reflect that yonder were cultivated fields, that there grew trees, that here were the dwellings of men, and that all have now vanished. The sands of the Desert were in ancient times remote from Egypt; and the Oases which still appear in the midst of this sterile region are the remains of fertile soils which formerly extended to the Nile."*

In the maritime plains and valleys of Peru the same cause is operating slowly, but with unremitting energy; the sea-sands are marching incessantly before the trade-wind, and threaten ultimate desolation. The sand has already surmounted the lofty hills which form the southern boundary of the beautiful valley of Lurin, and is flowing down in large waves over the cultivated ground. The same phenomenon is observable on the elevated plain which is called the Tablada, where the tops of the hills appear like Egyptian oases, and whence the sand is pouring down in enormous floods over the sugar-plantations of San Juan and Villa, in the valley of Rimac.†

46. FORMATION OF RECENT SANDSTONE IN CORNWALL.—On many parts of the shores of Scotland, sand-floods have converted tracts of great fertility into barren wastes; and on the northern coast of Cornwall an extensive district has been covered by drifted sand, which has become consolidated by

* See an Essay on the Moving Sands of Africa, in Professor Jameson's Translation of Cuvier's Theory of the Earth, p. 375. Sir G. Wilkinson, in his highly interesting work, questions the correctness of these inferences, as to the extent of the sand-floods, and asserts that at the present time the alluvial soil is on the increase, the deposits from the inundations of the Nile more than counterbalancing the inroads of the sands; and that the land now capable of cultivation in the valley of Egypt is greater than at the time of the Pharaohs.—*Manners and Customs of the Ancient Egyptians*, vol. i. pp. 218—222.

† Blackwood's Edinburgh Magazine for March, 1839.

the percolation of water holding iron in solution, and in some places forms ranges of low mounds, and hills forty feet high. This sandstone is an interesting example of a recent formation, and has been described by Dr. Paris (the late distinguished President of the College of Physicians), in one of the most lucid and instructive essays on modern deposits that has appeared in this country.* The sand has evidently been drifted from the sea by hurricanes, probably at a very remote period; it is first seen in a slight, but increasing, state of aggregation, on several parts of the shore in the Bay of St. Ives. Around the promontory of New Kaye, the sandstone occurs in various degrees of induration, from that of a friable aggregate to a stone so compact as to be broken with difficulty by the hammer, and which is used in the construction of buildings. Upon examining the stone with a lens, it appears to be principally made up of comminuted shells; and it is worthy of remark, that the shelly particles are frequently spherical, from the previous operation of water; and some portions of the rock closely resemble the ancient limestone called *oolite*, which will hereafter come under our notice. The rocks upon which the sandstone reposes are clay-slate and slaty limestone; and the water effecting their decomposition may have thus obtained the iron, alumina, and other mineral matters by which the loose sand has been converted into sandstone. The infiltration of water thus impregnated is a common and extensive cause of lapidification: at Pendean Cove, granitic sand is gradually hardening into breccia, by this process; and in the island of St. Mary, is becoming indurated by the slow action of this chalybeate.

47. SILICEOUS DEPOSITS.—Silex, or the earth of flint, a combination of the metallic base called silicon with oxygen, is a mineral which constitutes so large a portion of the rocks

* Appendix F.

and strata that it is computed to form, either in a pure or combined state, nearly one-half of the solid crust of the globe. The flints from our chalk-cliffs, and the pebbles of agate, quartz, flint, and chalcedony among the gravels on our sea-shores, are well-known examples of the usual varieties of silex.

I scarcely need observe, that this nodule of flint, obtained from a neighbouring chalk-pit, has once been in a soft or fluid state; for there are many sharp impressions of shells, and of spines of an echinus, on its surface.* We have already seen that water impregnated with carbonic acid gas is capable of holding lime in solution, and that travertine, limestone, and other calcareous deposits have originated from this agency; and although, even in the present advanced state of chemical knowledge, we are but imperfectly acquainted with the process by which any considerable proportion of flint can be dissolved in water, yet we have unquestionable proofs, that the solution of siliceous earth has been effected by natural processes on a very extensive scale. At the present moment, Nature, in her secret laboratories, is still carrying on a modification of the same process; and of this fact we have remarkable instances in the Geysers of Iceland, and in the Azores, and in New Zealand. A high temperature appears necessary to enable water to hold in solution a large quantity of silex; for we find that the thermal springs of volcanic regions are the only agents by which siliceous deposits and incrustations are at present produced. The difference between the modern siliceous *sinter* and the flint of the cretaceous strata appears to be referable to the subaerial deposition of the former and the submarine formation of the latter.

48. THE GEYSERS OF ICELAND.—The Geysers, or inter-

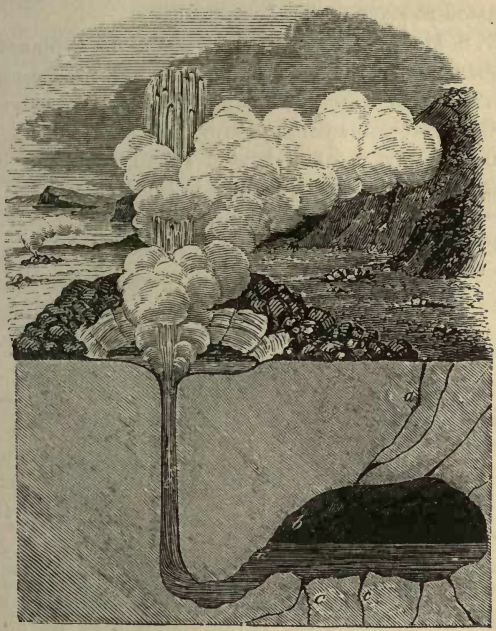
* *See* "Thoughts on a Pebble; or, a First Lesson in Geology." Eighth edition; 1849.

mittent boiling fountains, of Iceland have long been celebrated for possessing this property of depositing siliceous sinter in an extraordinary degree; holding a large quantity of silex in solution, and depositing it, when cooling, on vegetables and other substances, in a manner similar to that in which travertine is precipitated by the incrusting springs of which we have already spoken. Iceland may be considered as a mass of volcanic matter; the only substances not of igneous origin in the whole island being deposits of surturbrand (fossil wood or lignite), in which occur leaves, trunks, and branches of trees, with clay and ferruginous earth. These strata support alternating beds of basalt, tufa, and lava, which form the summit of the hill in which the vegetable remains occur.

The Geysers, of which there are a considerable number, are springs, or rather intermittent fountains, of hot water, which issue from crevices in the lava. A jet of boiling water, accompanied with a great evolution of vapour, first appears, and is ejected to a considerable height; a volume of steam succeeds, and is thrown up with prodigious force, and a terrific noise like that produced by the escape of vapour from the boiler of an engine. This operation continues sometimes for more than an hour, when an interval of repose of uncertain duration succeeds, after which the same phenomena are repeated. If stones are thrown into the mouth of the cavity from which the fountain has issued, they are ejected with violence after a short interval, and again jets of boiling water, vapour, and steam appear in succession. The eruptions of the "great Geyser," witnessed by Sir G. S. Mackenzie,* were preceded by a sound like the distant discharge of heavy ordnance, and the ground shook sensibly; the sound was rapidly repeated, when the water in the basin, after heaving several times, suddenly

* Travels in Iceland, in the summer of the year 1810, by Sir George Steuart Mackenzie, Bart.

rose in a large column, accompanied by clouds of steam, to the height of ten or twelve feet. The column seemed to burst, and, sinking down, produced a wave, which caused the water to overflow the basin. A succession of eighteen



LIGN. 13.—THEORETICAL DIAGRAM OF THE GEYSERS OF ICELAND.

or twenty jets now took place, some of which rose to a height of from fifty to ninety feet. After the last eruption, which was the most violent, the water suddenly disappeared, and sunk down the pipe in the centre, to a depth of ten feet; but in the course of a few hours the phenomena were repeated, and with increased energy. The basin of the

"great Geyser" is an irregular oval, about fifty-six feet by forty-six, formed of a mound of siliceous deposits about seven feet high; the channel through which the water is ejected being sixteen feet in diameter at the opening, but contracting to ten feet lower down; its perpendicular depth is estimated at sixty feet.

Sir G. S. Mackenzie proposed an ingenious explanation of these phenomena, which the diagram in the preceding page will serve to illustrate. He supposed that the water from the surface percolates through crevices (*Lign.* 13, *a*), into a cavity in the rock (*b*), and heated steam, produced by volcanic agency, rises through fissures in the lava beneath (*c*, *c*). The steam becomes in part condensed, and the water filling the lower part of the cavity (*d*) is raised to a boiling temperature, while vapour under high pressure occupies the upper part of the chasm. The expansive force of the steam becomes gradually augmented, and at length drives the water up the fissure or pipe (*e*), and a boiling fountain with jets of vapour is produced; this continues playing until all the water in the reservoir is expended, when the steam itself escapes with great violence, until the supply is exhausted.*

From Bunsen's experiments in 1846, it appears that, with regard to the great Geyser, at least, it is probable that it consists of an irregular tube, fed with rain and snow water, and heated from below, the peculiar form and capacity of which favours the heating of its contained water to a considerable amount above the boiling-point near its bottom; and that, when disturbing forces allow of ebullition towards the upper portion of the tube, portion after portion of the highly heated water successively burst into steam as the superincumbent pressure is removed from above.†

* Travels in Iceland, p. 229. See also Mr. R. Allan's interesting account of the condition of the Geysers in 1855, read before the British Association at Glasgow, vol. for 1855, Transact. Sect. p. 75.

† Chem. Rep. and Mem. Cavendish Soc. 1848, p. 346—349.

The siliceous concretions formed by these springs cover an extent of four leagues. M. Eugene Robert states, that this curious formation may be seen passing by insensible gradations from a loose friable state, the result of a rapid deposition, to the most compact and transparent masses, in which impressions of the leaves of the birch-tree, and portions of the stems, are distinctly perceptible, presenting the appearance of the agatized woods of the West Indies. Rushes, and various kinds of mosses, converted into a white siliceous rock, in which the minutest fibres are preserved, also occur; but on the margin of the Geysers, from the splashing of the water, the depositions resemble large cauliflowers; and, on breaking these masses, vegetable impressions are often discovered. Numerous thermal springs occupy the valley in the interior of the island, in the midst of which the Geysers are situated; it is evident that these waters rise from deep crevices, in which they have been heated by volcanic fires. The rivers proceeding from the springs often resemble milk in appearance, owing to the argillaceous bole which they take up in their passage among the siliceous concretions: such are the white rivers of Olassai. Mount Hecla, like all the mountains of Iceland, is entirely covered with snow, and no smoke appears on its summit. Accumulations of rolled masses of obsidian and pumice-stone form a layer on the flanks of the mountain thirty feet thick; stems and branches of the birch-tree occur in the midst of this bed; they are the remains of the ancient forests of the island, which the volcanic eruptions have entirely extirpated.*

49. Siliceous thermal waters of New Zealand.—The phenomena under review are being effected at the present moment, on a much grander scale, in the volcanic districts of New Zealand. The principal volcanic mountain of that country is Tongariro, which has an elevation of 6200 feet

* Bulletin de la Société Géologique de France.

above the level of the sea. Its crater is a quarter of a mile in diameter, and very deep; the sides are precipitous, and in some places overhanging, and the entire area is always covered with steam. From this crater streams and torrents of boiling water, highly charged with silex, are constantly issuing forth; and, flowing down the flanks of the mountain in cascades and torrents, they empty themselves into lakes near its base, and deposit in their course siliceous sinter in great abundance, incrusting leaves, branches, and other extraneous substances. The whole of the surrounding country for several miles is studded with lakes and pools, and fountains of hot and boiling water; and groups of mud-ponds, or stufas, occur in considerable numbers. Some of the boiling torrents of the mountain find their way to the delta of the river Waikato, and cover a space of two miles square with an assemblage of thermal springs. The surface of this area appears to be only a thin crust of pumice and a friable sulphureous earth, with chalcedonic and siliceous incrustations, spread over volcanic caverns.

The most stupendous of these boiling pools is partly surrounded by a cliff sixty feet high, which is oxidized, corroded, and undermined from the effects of the heated vapours, which are continually issuing forth in jets. At the base of this cliff the pond is constantly boiling with a white foam, and throwing up fountains eight or ten feet high, with great noise and violence. Silex is thrown down by the boiling waters in the state of stalagmitic concretions, and this deposit resembles in colour and solidity the flint of the English chalk. This generally insoluble mineral is here held in solution by the alkaline elements and very high temperature of the water.

"Another and still more striking example of a thermal lake," observes Dr. Dieffenbach, from whose interesting work on New Zealand the preceding notice is taken, "is that of Rotu-Mahana. Imagine a deep lake of a blue colour

surrounded by verdant hills, and in this lake several islets, some showing the bare rocks, while others are covered with shrubs; while on all of them steam issues from a hundred openings between the green foliage without impairing its freshness. On the opposite side is a flight of broad steps of the colour and aspect of white marble, with a rosy tint from siliceous incrustations, over which flowed a cascade of boiling water into the lake. A part of this lake is separated from the rest by a ledge of rocks, forming a lagoon in a state of ebullition, which discharges its waters into the Rotu-Mahana."

These modern siliceous formations are facts of great interest and importance; for they prove, in the clearest manner, that the most insoluble and refractory substance may be reduced to a liquid state, and again become consolidated, and assume numerous modifications, merely by the agency of thermal waters; hence the envelopment of the delicate corals, shells, &c., which are so abundant in the flints of the chalk, may be readily explained.

50. ARTIFICIAL SOLUTION OF SILEX.—The natural processes above described have been successfully imitated in a series of experiments, conducted with great sagacity by Mr. Jeffreys, with the view of determining whether silex is soluble in heated water, without the presence of alkalies or other chemical agents.* The following is a concise account of these important experiments.

* Ransome's artificial siliceous stone, a material now extensively used in architecture, is based on the well-known chemical fact, that flint, or any siliceous substance, is perfectly soluble when subjected to the action of caustic alkali (soda or potash) at a high temperature in a steam-boiler, or in cylinders communicating with such boilers. Flint (silex or silica) is a compound of oxygen with a peculiar base (silicon), and is technically termed an acid, though it has not the ordinary properties of acids. On being heated with caustic soda at a very high temperature, there is formed a thick jelly-like transparent fluid of a pale straw-colour, which is a hydrated silicate of soda, containing 50 per cent. of water; by exposure to

A large boiler or kiln, used in India for vitrifying brown stone-ware, was heated by four exterior furnaces, each six feet long and five wide. Between each of these furnaces and the kiln a deep pit was made, and filled to a height of three feet with water, which was renewable from without. Some felspathic and siliceous minerals were placed in the direction of the current just within the kiln; and upon some of the arches a few earthenware vessels were placed, that any action upon them might be observed. Below a full red heat but little effect was perceived; but at a temperature above that of fused cast-iron, a rapid solution of mineral matter took place; this heat was continued for ten hours. When the kiln was opened, more than a hundred-weight of mineral matter had been dissolved and carried away in the vapour. The wall of the kiln was eaten away, and presented a corroded and unglazed surface, like loaf-sugar partially melted by water: and there was no appearance of the smooth glazed surface, which invariably attends the action of an alkali on a siliceous substance. Some of the earthenware vessels were partially eaten through; but on the uppermost arch, where the heat was only a full red, a curious phenomenon appeared; the articles there had received, exterior to their own glazing, and loosely incrusting it, a complete frosted siliceous coating, having the appearance of a candied surface. This was evidently a precipitation from the vapour; in fact, a hoar-frost of silex. There was from half an ounce to an ounce on each vessel, and altogether several pounds were thus precipitated; but by far the greater part of the vapourized mineral was, as might be expected, carried away by the current, and dissipated in the air. This powerful action was

the air, or to heat, part of the water evaporates, and the mass solidifies into a substance capable of scratching glass. It is this fluid silicate of soda combined with sand and other materials, which, raised to red heat in a kiln, is fused into a glass, and thus forms a durable compound as indestructible as flint itself.

apparently entirely due to the presence of water; there being at all times the same quantity of alkali present in the fuel, whatever that might have amounted to, without producing such an effect. The experiment is conclusive as to the solvent power of water at a very high temperature on silica and siliceous rocks; for the action cannot be attributable to the alkalies, because, under precisely similar conditions, the experiment failed when there was no water; and besides, each pound of alkali would have had to dissolve forty pounds of silica. Mr. Jeffreys has in fact performed, on a small scale, the same operation which is incessantly going on in the volcanic regions of Iceland and New Zealand, and established the potency of heated water and vapour to effect the solution of silex.*

51. HERTFORDSHIRE PUDDING-STONE.—We have before us numerous examples of conglomerates formed by carbonate of lime; in other words, aggregations of pebbles, sand, shells, and corals, cemented together by calcareous spar; and others by ferruginous infiltrations: but this specimen is a congeries of rounded flint-pebbles, imbedded in a siliceous paste. This conglomerate is commonly called Hertfordshire pudding-stone, and was formerly in much request with lapidaries; for the cement being as hard and solid as the pebbles themselves, the stone admits of being cut and polished into a great variety of ornaments. In ancient times, it was used for querns or hand-mills. The formation of this rock must have resulted from a stream of siliceous matter having flowed through a bed of gravel, and cemented the pebbles into a solid mass, while those portions which the liquid flint did not reach remained as loose water-worn materials.

But there are many very hard sandstones composed entirely of siliceous granules, which appear to have been consolidated simply from the effect of great pressure, there

* See an account of Mr. Jeffreys' experiment in Report of the British Association of Science, 1840. (Transactions of the Sections.)

being no cementing medium; the rock, when broken, appearing like the fractured surfaces of fine sugar.*

It is not my intention in this lecture to dwell on the silicification† of the remains of animals and plants; it will suffice to remark, that in silicified wood the most minute vegetable structure may often be detected, although the specimens will strike fire with steel; and that the most delicate and perishable animal tissues are often preserved in flint.

52. EFFECTS OF HIGH TEMPERATURE.—The phenomena presented to our notice in this investigation of the Geysers of Iceland, and other natural solutions of silex in thermal waters, lead to the consideration of another agent in the transmutations that take place in the crust of the globe. It must be obvious to every intelligent mind, that beds of loose and porous materials can have acquired hardness and solidity only by one of the following processes; namely, either by matter dissolved in a fluid and deposited among the porous masses in the manner just described, or by the reduction of the materials by heat into a state of softness or fusion, and their subsequent conversion, by cooling, into a solid mass.‡ Fire, or, to speak more correctly, a high temperature, how-

* A consolidation of this kind can be produced artificially. In the experiments made for the trial of the strength of gunpowder, leathern bags filled with sand are put into the mortar which is to receive the cannon-ball propelled by the powder from another gun at the distance of only fifty feet. The sand is frequently compressed, by the percussion of the ball, into a mass of sandstone, sufficiently firm to remain solid and bear handling; and this sandstone is perfectly free from any cement. The consolidating power of great pressure has lately been ingeniously applied to various purposes; among others, to the formation of tesseræ from porcelain-earth, and of graphite or plumbago, fit for the finest pencils, from the rubble of rejected ore formerly thrown by as useless. This rubble is reduced to an impalpable powder, and then subjected to great pressure in moulds: this prepared mineral is now generally employed for the best lead-pencils. Dawson's patent fuel, formed of coal-dust and water forcibly compressed, is another instance of this kind of consolidation.

† Petrifaction by flint. ‡ Playfair.

ever induced (whether by electro-magnetic influence, or by central or medial sources of heat), and water are therefore the chief agents by which the mineral masses composing the crust of our planet have been and are still being modified. We have already seen how vast are the changes which result from the effects of water; we must now take a rapid survey of the influence which caloric is capable of exerting; an influence far more universal and varied than we may at first be prepared to expect.

The expansive power which heat exerts on most substances, and its conversion of the most solid and durable bodies, first into a fluid, and lastly into a gaseous state, are phenomena so familiar as to require no lengthened comment. But the effects of heat are found to vary according to the circumstances under which bodies are submitted to its influence; hence the changes induced by high temperature beneath great pressure are totally different from those effected by fire on the surface, under the ordinary weight of the atmosphere. A familiar example will serve to illustrate my meaning. Chalk consists of lime combined with carbonic acid; and as, for agricultural and other economical purposes, it is desirable to have the lime in its pure state, the chalk, or limestone, is exposed to great heat, in kilns erected in the open air, until all the carbonic acid gas is dissipated,—when the stone is said to be burnt into quicklime. In the specimens before us the same substance is seen in the state both of chalk and lime. It may readily be conceived, that, if this operation were conducted beneath such a degree of pressure as would prevent the escape of the gaseous elements, the formation of quicklime would not take place; the chalk would be fused, and the carbonic acid, released from its present relation with the calcareous particles, would enter into other combinations, and the mass, when cooled, be wholly different from the product of the lime-kilns, formed by the same agency in the open air. Experiments have proved that

this opinion is correct. Sir James Hall exposed pounded chalk to intense heat, under great pressure, and it was fused, not into lime, but into crystalline marble: even the shells enclosed in the chalk underwent the same transmutation, yet preserved their forms.* That analogous changes have been effected by natural operations we have abundant proof; but in this stage of our inquiry it is only necessary to remark, that, where ancient streams of lava have traversed chalk, the latter invariably possesses a crystalline structure. We shall hereafter find, in accordance with the philosophical theory of Dr. Hutton, that all the ancient strata have been more or less modified by heat, acting under great pressure and at various depths; and that the present position and direction of the rocks composing the crust of the globe have been produced by the same cause.† The Huttonian theory, indeed, offers a satisfactory explanation of a great proportion of geological phenomena, and enables us to solve many of the most difficult problems in the science; and it is but an act of justice to the memory of its illustrious founder, and of his able illustrator, Professor Playfair, to state that this theory, corrected and elucidated by the light which modern discoveries have shed upon the physical history of our planet, is that embraced by the most distinguished modern geologists.

53. VOLCANIC AGENCY.—Of the activity and power of the agent to which these remarks more immediately refer, the currents of melted rocks, called lavas, ejected through crevices and fissures of the earth, accompanied with evolu-

* From a table drawn up with due caution by Sir James Hall, it is proved that under a depth of the sea, not exceeding one-third of a mile, chalk, subjected to great heat, would be converted into a crystalline limestone, and that at a depth of little more than a mile it would be in a state of fusion, provided there were no refrigerating causes in action.

† See Playfair's Illustrations of the Huttonian Theory, vol. i. p. 33, *et seq.* Edin. 1822.

tions of heat and vapour, afford the most striking proofs; and the volcano, with its frequent concomitant, the earthquake, have in all ages excited the terror and astonishment of mankind. It would be foreign to the design of this discourse, to dwell upon the nature and causes of volcanic action. Dr. Daubeny,* Mr. Scrope,† and others, have published highly interesting treatises on the subject; and Lyell and Delabeche have given admirable sketches of volcanic phenomena.‡ I will only advert to the increased temperature of the earth in proportion as we descend from the surface towards the interior, and the profound depths from which thermal waters take their rise, as tending to support the opinion, that volcanic eruptions are occasioned by causes which are constantly in action in the interior of the globe. We shall hereafter have occasion to demonstrate that dislocations of the strata, elevations of the bottom of the ocean, subsidences of the land, and eruptions of melted mineral matter, have taken place from the earliest periods within the scope of geological inquiries.

The expansive power of caloric, even in ordinary circumstances, is very considerable, as is shown by the instrument called a *pyrometer*, which illustrates a fact continually presented to our notice, namely, the expansion of a bar of metal by heat, and its contraction, by cooling, into its original dimensions. The expansion of solid bodies by heat, when effected on a large scale, gives rise to many interesting phenomena. The careful experiments made by Colonel Totten, on the expansion of granite, marble, and other rocks, by variations of temperature, have shown that the mere expansion, or contraction, of extensive beds of these materials will account for the elevation and subsidence of

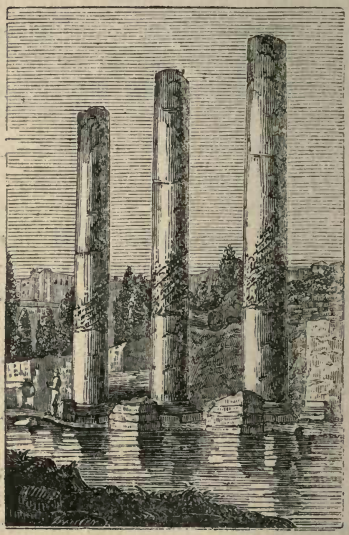
* Daubeny's Lectures on Volcanos, 1826.

† Scrope's Considerations on Volcanos, 1825· and Geol. Journ. vol. xii., 1856.

‡ Principles of Geology: Geological Observer.

considerable tracts of country, and explain many analogous phenomena.*

54. SUBSIDENCE AND ELEVATION OF THE TEMPLE OF JUPITER AT PUZZUOLI.—One of the most interesting examples of local elevation and subsidence, apparently resulting from this cause, is that afforded by the remains of the celebrated temple of Jupiter Serapis, at Puzzuoli.



FIGN. 14.—REMAINS OF THE TEMPLE OF JUPITER SERAPIS, AT PUZZUOLI.
(From Sir C. Lyell's Principles of Geology.)

These ruins are situated on the northern shore of the Bay of Baiæ, at no great distance from the Solfatara, and consist of the remains of a large building of a quadrangular form, seventy feet in diameter; the roof of which was supported by twenty-four granite columns, and twenty-two of

* American Journal of Science, vol. xxii. See also Babbage's remarks on similar phenomena, Quart. Geol. Journ. vol. iii. p. 206, &c.

marble, each formed of a single stone. Many of the pillars are broken and their fragments strewed about the pavement, but three remain standing, and on them are inscriptions, not traced by the Greeks or Romans, but by some of the simplest forms of animal existence, which have here left enduring records of the physical changes that have taken place on these shores, since man erected the temple in honour of his imaginary gods. The surface of the columns, the tallest of which is forty-two feet in height, is smooth and uninjured to an elevation of about twelve feet from the pedestal, where a band of perforations, nine feet wide, made by marine boring mussels (*modiola lithophaga*), commences; and above this, that is, at the height of twenty-one feet from the pedestal, these cavities disappear. The hollows, many of which still contain shells, sand, and microphytes, are of an elongated elliptical shape, and are so numerous and deep, as to prove unquestionably that the pillars were submerged in sea-water, the base and lower portions having been protected from the depredations of the boring shells by accumulations of rubbish and tufa; while the upper parts projected above the waters, and consequently were beyond the reach of the *lithodomi*.* The platform of the temple is now about one foot below high-water mark; and the sea, which is only forty yards distant, penetrates the intervening soil. The upper part of the band of perforations is now at least twenty-three feet above the level of the sea; and yet it is evident that the columns were once immersed in salt water for a long period. It is equally clear that they have since been elevated to their present height, and yet have maintained their erect position, amid the extraordinary changes to which they were subjected; thus incontrovertibly proving, that the relative level of the land and sea, on that part of the Mediterranean coast, has changed more than once since

* *Lithodomi*, stone-borers; from *lithos*, stone, and *doma*, habitation.

the Christian era; each movement, both of subsidence and elevation, having exceeded twenty feet.* And there, at the present moment—

> "Those lonely columns stand sublime,
> Flinging their shadows from on high,
> Like dials which the wizard Time
> Had raised to count his ages by!"—MOORE.

55. HISTORICAL EVIDENCE.—Fortunately, historical evidence throws some light on the respective dates of the most considerable changes of level that the area on which the temple is situated has undergone. From inscriptions recording the embellishment of the temple by Septimus Severus and Marcus Aurelius, we learn that the building was entire, and occupied its original position, in the third century. In 1198 the eruption of the volcanic lake of the Solfatara took place, and was accompanied by earthquakes; a subsidence of the coast followed, and sunk the temple to a depth that submerged the columns in water to a height above the band of perforations. This state of things must have continued until the beginning of the sixteenth century; for the flat district called La Starza, on which the temple stands, is described by contemporary observers as being covered by the sea in 1530. Eight years afterwards earthquakes were very frequent and violent along that part of the Neapolitan coast, and on the 29th of September a volcanic eruption suddenly burst forth, and threw up, in a single night, a mound of pumice and ashes 450 feet high, and a mile and a half in circumference, which still remains, and is called Monte Nuovo. During this catastrophe the coast on the north of the Bay of Baiæ was permanently elevated to the height of twenty feet, and formed a tract 600 feet in breadth, including the area occupied by the ruins of the temple, which were also elevated above the reach of the water, several of

* For a full account of the phenomena, see Principles of Geology, 9th edit. p. 507.

the columns retaining their original position.* These interesting relics of antiquity appear to have been wholly neglected until 1750, when the shrubs and weeds with which they were overgrown and concealed were removed, and the earth accumulated in the court of the temple cleared away. For the last thirty or forty years a slow subsidence of this coast appears to have been going on, and the floor of the temple is now often under water.†

56. CAUSES OF THESE CHANGES.—Mr. C. Babbage attributes the tranquil elevation and depression of the temple to the contraction and expansion of the strata on which it was built; the sources of volcanic action in the surrounding country being very numerous, and a hot spring still existing on the land-side of the ruins. The change of level is therefore easily accounted for, by supposing the temple to have been built on the surface, when the rocks beneath were expanded by the effects of a high temperature, and that they subsequently contracted by slow refrigeration. When this contraction had reached a certain point, if a fresh accession of heat from the neighbouring volcano took place and increased the temperature of the strata, they would again expand, and thus raise the ruins to their present level.

Mr. Babbage carries out these views to explain the elevation of continents and mountain-ranges, assuming the following facts as the basis of his theory:—

1st. As we descend below the surface of the earth, the temperature increases.

2ndly. Solid rocks expand by being heated, but clay and some other substances contract.

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* See Professor James Forbes's Notices on the historical evidence relating to the elevations and subsidences of the Temple of Jupiter at Puzzuoli, and of the adjacent coast.—*Brewster's Edinburgh Journal of Science, second series*, vol. i. p. 280.

† See a letter addressed to the author by Mr. Hullmandel, Appendix G.

3rdly. Rocks and strata of dissimilar characters present a corresponding difference as conductors of caloric.

4thly. The radiation of heat from the earth varies in different parts of its surface; according as it is covered by forests, mountains, deserts, or water.

5thly. Existing atmospheric agents, and other causes, are constantly changing the condition of the surface of the globe.

Thus, wherever a sea or lake is filled up by the wearing down of the adjacent lands, new beds are formed, conducting heat much less quickly than the water; while the radiation from the surface of the new land will also be different. Hence, any source of caloric, whether partial or central, which previously existed below that sea or lake, must increase the temperature of the strata underneath to a much higher degree than before, because they are now protected by a bad conductor;* and their expansion must therefore elevate the newly-formed deposits above their former level;—thus the bottom of an ocean may become a continent. The whole expansion, however, resulting from the altered circumstances, may not take place until *long* after the filling up of the sea; in which case its conversion into dry land will result partly from the accumulation of detritus, and partly from the elevation of the bottom. As the heat now penetrates the newly-formed strata, a different action may be induced, the beds of clay or sand may become consolidated, and instead of expanding, may contract. In this case, either large depressions will occur within the limits of the new continent, or, after another interval, the new land may again subside, and form a shallow sea. This sea may be again filled up by a repetition of the same processes as before;—and thus alter-

* Sir John Herschel observes, that this process is precisely similar to that by which a great coat, in a wintry day, increases the feeling of warmth; the flow of heat outwards being obstructed, and the surface of congelation removed to a distance from the body by the heat thereby accumulated beneath the new covering.

nations of marine and fresh-water deposits may occur, having interposed between them the productions of the dry land.*

To review the physical changes which have taken place around the Bay of Naples would prove highly interesting, but my limits will only permit me to observe, that whole mountains have been elevated on the one hand, and temples and palaces submerged beneath the sea on the other. In our sister island we have evidence of former changes of a like nature, and which are alluded to by our inimitable lyric poet, in the following beautiful lines:—

"On Lough Neagh's banks as the fisherman strays,
When the clear cold eve 's declining,
He sees the round towers of other days
In the wave beneath him shining!

"Thus shall memory often, in dreams sublime,
Catch a glimpse of the days that are over;
Thus, sighing, look through the waves of time
For the long faded glories they cover!"—MOORE.

57. ELEVATION OF THE COAST OF CHILI.—One of the most remarkable modern instances of the upheaval of an extensive tract of country, is that recorded by the late Lady Calcott (then Mrs. Maria Graham) as having been produced by the memorable earthquake which visited Chili in 1822, and continued at short intervals until the end of 1823. The shocks were felt through a space of 1200 miles, from north to south. At Valparaiso, on the morning of the 20th of November, it appeared that the whole line of coast had been raised above its level; an old wreck of a ship, which could not previously be approached, was now accessible from the land; and beds of oysters, not before known in that locality, were brought to light. "When I went to examine the coast," says Lady Calcott, "although it was high-water, I

* Proceedings of the Geological Society, March, 1834, vol. ii. p. 75; and Geol. Journ. vol. iii. p. 206; vol. xii. p. 366.

found the ancient bed of the sea laid bare and dry, with beds of oysters, mussels, and other shells adhering to the rocks on which they grew, the fish being all dead, and exhaling most offensive effluvia. I found good reason to believe that the coast had been raised by earthquakes at former periods in a similar manner; several ancient lines of beach, consisting of shingle mixed with shells, extending in a parallel direction to the shore, to the height of fifty feet above the sea." * Part of the coast thus elevated consists of granite; subsequent observations have proved that the whole of the country was raised, from the foot of the Andes to far out at sea; the supposed area over which the elevatory movements extended being about 100,000 square miles; a space equal in extent to half the kingdom of France. Mrs. Somerville mentions, that a further elevation to a considerable extent has also taken place along the Chilian coast, in consequence of the violent earthquake of 1835.†

58. RAISED SEA-BEACH AT BRIGHTON.‡—Examples of such changes occur in almost every part of the world, and there is perhaps no considerable extent of country which does not afford some proof that similar physical mutations have taken place in modern times. And, although we have not a temple of Serapis on our shores, yet the cliffs from Brighton to Rottingdean afford unquestionable evidence that the relative level of land and sea has undergone great changes within, to speak geologically, a comparatively recent period. The cliffs along the coast, from New Shoreham to Rotting-

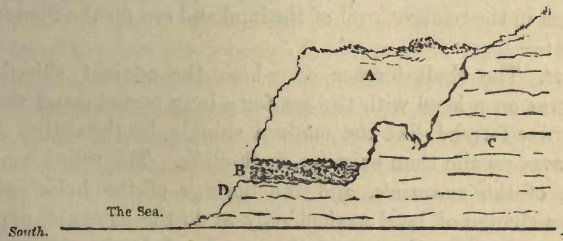
* Geological Transactions, second series, vol. i. p. 415.

† The late earthquake in New Zealand, on January 23, 1855, has resulted in the uprise of an extensive area of land, about Wellington, to a general height of about five feet. See Sir C. Lyell's Lecture, Royal Institution Notices, March 7, 1856, p. 212.

‡ The geological character of the cliffs at Brighton, and the occurrence of bones of elephants and other mammalia in those beds, were first described in my "Fossils of the South Downs," 1822.

dean, are composed of layers of chalk-rubble, with angular unrolled flints and interspersions of clay and loam; the whole being an accumulation of but slightly water-worn materials, deposited at some very remote period in an estuary or bay.* The base of the cliffs, to the height of a few feet, consists of the chalk-strata, which may be seen at low water extending far out to sea, partially covered here and there by shingle and sand. Between the chalk and the superincumbent mass above described, is a bed of rolled chalk-flints, pebbles, and sand, with boulders of granite, porphyry, and other rocks, foreign to the south-east of England; in fact, a sea-beach formed in the same manner as the present bed of shingle which skirts the base of the cliffs. Among the pebbles of this ancient beach, are rolled masses of chalk and limestone, full of perforations made by boring-shells.

These originally partially stratified accumulations, deposited beneath the waves, now constitute a line of cliffs, extending for miles along the sea-coast. The annexed diagram (*Lign.* 15)



LIGN.—15. ELEVATED STRATA AND BEACH AT BRIGHTON, EAST OF KEMP TOWN.

A, Elephant-bed; B, Ancient bed of shingle; C, the Chalk; D, Terrace of Chalk beneath the ancient sea-beach.

represents a vertical section, as seen in those places where the inroads of the sea have extended to the chalk-strata, and

* For different opinions on the origin and age of this chalk-rubble or Combe-rock, see Geol. Journ. vol. vii. p. 126 and 365, and vol. xiii. p. 64.

the face of the ancient cliff is exposed, the newer deposits being shown in profile from south to north; these consist of the following:—

1. (A), Chalk-rubble, loam, &c., obscurely stratified; this deposit, from its containing many teeth and bones of extinct species of elephant, rhinoceros, ox, horse, and deer, I have named the Elephant-bed; it constitutes the upper three-fourths of the cliffs.
2. (B), Shingle, or sea-beach, and sand, several feet above high-water mark, containing boulders of granite, porphyry, and quartz-rock, and occasionally remains of elephants, &c., as in the deposit above it. This ancient shingle, which, from the inroads of the sea on the cliffs beyond Kemp Town, now extends but a short distance inland, is constantly found beneath the loam and clay, several hundred yards north of the shore, in the western part of Brighton. In wells sunk in the Western road, the shingle-bed was reached at the depth of fifty-four feet.
3. (C), The undisturbed chalk, which forms a sloping cliff, inland, behind the elephant-bed (A) and shingle (B), passes under the latter, and appears as a terrace at the foot of the present cliffs (D).*

These appearances demonstrate the following sequence of changes in the relative level of the land and sea on the Sussex shores:—

First. The chalk-terrace on which the ancient shingle rests was on a level with the sea for a long period; and the beach was formed, like the modern shingle, by the action of the waves on the then existing chalk-cliffs. The rolled condition of the materials, and the borings of the *lithodomi*, prove a change of level as decidedly as do the bands of perforations in the columns of the temple of Jupiter at Puzzuoli.

Secondly. The whole line of coast, with the shingle (B), was submerged to such a depth as to admit of the deposition of the uppermost strata (A).

* See Geology of the South-East of England, p. 30; Fossils of the South Downs, p. 277; Medals of Creation, 2 edit. vol. ii. p. 852; and Quart. Geol. Jour. vol. vii. p. 365.

Lastly. The cliffs were raised to their present elevation, and at this period the formation of the existing sea-beach commenced.

Here, then, we have unquestionable evidence that the Sussex shores have been subjected to changes similar to those produced by earthquakes on the Chilian coast.

A phenomenon of a like nature, but of a far more ancient period, is observable at Castle Hill, near Newhaven, about eight miles east of Brighton; there, immediately beneath the turf, is a regular sea-beach with oyster-shells, many feet in thickness, forming the summit of the chalk-cliffs, 150 feet above the level of the sea.

Elevated beds of shingle, of comparatively recent epochs, occur frequently along the coasts of Scotland, the Western Isles, Ireland, and England.

59. ELEVATION OF SCANDINAVIA.—Having thus adduced a few striking proofs of the mutations which the land has undergone in past times, we are led to inquire—is this change still going on?—is the alternate subsidence and elevation of the land the effect of a law of nature, established from the commencement of the present condition of our planet, and destined to continue in action while its physical constitution remains the same? We may unhesitatingly reply in the affirmative, for there are innumerable proofs that this law has been in constant action from the earliest periods; and I now proceed to adduce an instance in which the elevation of a whole country is actually taking place, unsuspected by the busy multitude which inhabit its towns and cities, and known only by the researches of the natural philosopher. I allude to Scandinavia, which is slowly and visibly rising, from Frederickshall, in Sweden, to Abo, in Finland, and even, perhaps, as far as St. Petersburgh; while the adjacent coast of Greenland is suffering a gradual depression. The state, therefore, is one of oscillation, the

waters appearing to sink at Torneo, and to retain their former level at Copenhagen.

The opinion that Sweden is in this state of change is no new idea; it was long since entertained by Celsius and other Swedish philosophers.* Sir C. Lyell, who has twice visited Scandinavia with the view of determining this interesting question, expresses himself fully convinced that certain parts of Sweden are undergoing a gradual rise, to the amount of two or three feet in a century; while other tracts, farther to the south, appear to have experienced no movement.† He visited the shores of the Bothnian Gulf, between Stockholm and Gefle, and the western coasts of Sweden, districts particularly alluded to by Celsius. Upon examining the marks cut by the pilots, under the direction of the Swedish Academy of Sciences, in 1820, the level of the Baltic, in calm weather, was found to be several inches lower than the marks, and from two to three feet below those made seventy or a hundred years ago. Similar results were obtained on the side of the ocean, and in both districts the testimony of the inhabitants agreed with that of their ancestors, as recorded by Celsius. On the shores of the Northern Sea, there are banks of recent shells, at various heights, from 10 to 200 feet; and on the side of the Bothnian Gulf, between Stockholm and Gefle, there are deposits containing fossil shells of the species which now

* Celsius remarks, "that several rocks on the shores of the Baltic, which are now above the water (A. D. 1730), were, not long before, sunken rocks, and dangerous to navigators; one especially, which, in the year 1680, was on a level with the surface of the water, is twenty and a half Swedish metres above it. From an inscription, near Aspô, in the Lake Melar, which communicates with the Baltic, engraved, as is supposed, above 500 years ago, the land appears to have risen no less than thirteen Swedish feet."—*Playfair's Illustrations of the Huttonian Theory*, p. 436, edit. 1822.

† Philosophical Transactions, 1835. Principles of Geology, Ninth Edition, p. 519.

inhabit the brackish waters of that sea. These occur at different elevations, from one to a hundred feet, and sometimes extend fifty miles inland. Some of the shells are marine, and others fluviatile; the marine species are identical with those now living in the ocean, but are small in size, and never present the average dimensions of those which live in water sufficiently salt to enable them to reach their full development. The specimens before us were collected by Sir C. Lyell at Uddevalla, in Sweden, from the summit of cliffs twenty feet above the level of the sea; they consist of marine species which still inhabit the neighbouring waters.

60. MUTATIONS IN THE RELATIVE LEVEL OF LAND AND SEA.—Of the reality of these changes in the relative level of the land and of the Northern Ocean there cannot exist a doubt; but the mind is so accustomed to associate the idea of stability with the land, and of mutability with the sea, that it may be necessary to offer a few additional remarks on these highly interesting facts. As it is the property of all fluids to find their own level, it is obvious that, if the level of the sea be elevated or depressed in any one part, that elevation or depression must influence the whole surface of the ocean, and the level therefore cannot be affected by local causes. But movements of the land may take place, and the effect extend over whole countries, as in South America,—or along lines of coast, as in Sussex,—or be confined to a single island,—or even to the area of a temple, as at Puzzuo *

But while the land is rising in the more northern latitudes, it appears to be sinking on the shores of the Mediterranean. Breislak mentions† that numerous remains of buildings are to be seen in the Gulf of Baiæ; ten columns of granite, at the foot of Monte Nuovo, are nearly covered by the sea, as are the ruins of a palace built by Tiberius in the island of

* See Playfair's admirable commentary on this geological problem, "Illustrations," p. 433.

† Playfair.

Capri. Thus while the level of the sea is becoming lower in the north, from the elevation of the land, it is rising in the Mediterranean, from the sinking of its coasts. Now, as all the parts of the ocean communicate, the water cannot permanently rise in one part and sink in another, but must rise and fall equally to maintain its level; we must therefore consider it as demonstrated, that these changes are solely dependent on the elevation and depression of the land. If we bear in mind the insignificance of the masses affected by these operations, as contrasted with the earth itself (see page 35), we may readily conceive that, as fissures and inequalities are produced in the varnish of an artificial globe by heat and cold, in like manner the elevation of mountain-chains, and the subsidence of whole continents, may be occasioned by the expansion or contraction of portions of the earth's crust, from sudden changes in the internal temperature of the globe (see above, p. 109).

61. RETROSPECT.—In this rapid sketch of the geological phenomena, which an examination of the surface of the earth presents to our notice, I have doubtless dwelt on several subjects familiar to many of my readers. But, as one of our ablest geologists* has remarked, "the teacher of geology must suppose himself called on to answer questions both concerning the facts of the science and the inferences to be deduced therefrom: and his instructions will be so much the more successful as he takes these questions in the most natural order of their occurrence, and answers them most completely and satisfactorily. In doing this he is not at liberty to neglect even elementary truths, for, if these were passed over in compliment to such as have made progress in the science, those for whose advantage he is especially interested would be called to the unreasonable task of labouring without instruments, and of theorizing without intelligible data."

* Professor John Phillips.

From the vast field of inquiry over which our observations have extended, it may be useful to offer a brief summary of the leading principles that have been enunciated, and the facts on which they are founded. By the most profound investigations of which the human mind is capable, we learn that our earth is one of myriads of spherical bodies, revolving round certain luminaries; and that these bodies occur in every variety of condition, from that of a diffuse luminous vapour, to opaque solid globes, like our own. All the materials of which the earth is composed may exist either in a solid, fluid, or gaseous state; and simply by a change of temperature, or by electro-chemical agency, every substance may undergo a transition from one state to the other. Water, existing as ice, fluid, or vapour, and separable into two invisible gases, offers a familiar example of a body constantly exhibiting these transmutations; and mercury, of a metal which, though generally in a fluid state, becomes, when exposed to a very low temperature, a solid mass like silver. The relative position of land and water, and the inequalities on the surface of the earth, are subject to constant changes, which are regulated by certain fixed laws. The principal causes of the degradation of the land are atmospheric agencies, variations of temperature, the action of running water, and of glaciers, icebergs, &c., by which the disintegrated materials of the land are transported into the bed of the ocean. The mud, sand, and other detritus thus produced are consolidated by certain chemical changes which are in constant activity, both on the land and in the depths of the ocean, and new rocks are thus in the progress of formation. But the conjoint effect of these operations is unremitting destruction of the surface of the land; and, were there no conservative process, the whole of the dry land would disappear, and the earth be covered by one vast sheet of water. The globe, however, possesses an internal source of heat, and, whether this exists as a central nucleus of high temperature, or as

medial foci,—whether it be dependent on the assumed original nebulous state of the earth, or produced by chemical or electro-magnetic forces acting on the mineral substances contained in the interior of our planet,—does not affect the present inquiry. This internal heat, however induced, must occasion constant changes in the relative level of the land and water; elevating and depressing whole continents,—converting the bed of the sea into dry land,—and submerging the dry land into the abyss of the ocean. The volcano and the earthquake are the effects of its local and paroxysmal energies,—the quiet and insensible elevation and subsidence of the land, of its slow but certain operation. By this antagonist power the accumulation of the spoils of the land, which the rivers, waves, and currents have carried into the bed of the ocean, are again brought to the surface, and form the elements of new islands and continents; and by the organic remains discovered in the strata we trace the nature of the countries whence these spoils were derived. In the deltas and estuaries of modern times,—in the detritus accumulating in the beds of the ocean,—in the recent tracts of limestone forming on the sea-shores,—beneath the cooled lava-currents erupted from existing volcanos,—the remains of man and of his works, and of the animals and plants which are his contemporaries, are found imbedded.

The dynamical effects of elevation appear to be referable to three great divisions:—1. The gradual rising of ridges through large spaces of the earth's crust, and the consequent production of longitudinal fissures and lines of volcanic vent; 2. The long-continued protrusion and eruption of igneous rocks along such lines of vent; and, 3. Local eruptions and protrusions, producing valleys of elevation, dislocations of the strata, and other phenomena that terminate in ordinary volcanic action.

Such are the deductions derived from the phenomena which have been submitted to our examination. To the mind pre-

viously unacquainted with the elements of geology, I am ready to acknowledge that to attribute mutability to the rocks and the mountains must appear as startling and incredible as did the astronomical doctrines of Galileo to the people of his times; but the intelligent reader, who has attentively considered the facts presented, even in this brief survey, cannot, I conceive, refuse assent to the inferences thus cautiously obtained. As we proceed in our investigations, we shall find that, from the earliest period of the present physical condition of our planet, its surface has undergone repeated modifications in the relative distribution of the water and the land; and, as the rocks and mountains and plains have been subjected to perpetual mutation, the element which has hitherto been considered as the type of mutability can alone be regarded as having suffered no change. This idea is finely embodied by Lord Byron in the following sublime apostrophe to the ocean, with which I will conclude this discourse:

"Thy shores are empires, changed in all save thee,—
Assyria, Greece, Rome, Carthage, what are they?
Thy waters wasted them while they were free,
And many a tyrant since; their shores obey
The stranger, slave, or savage; their decay
Has dried up realms to deserts:—not so thou,
Unchangeable, save to thy wild waves' play—
Time writes no wrinkle on thine azure brow—
Such as Creation's dawn beheld, thou rollest now!"

CHILDE HAROLD, Canto iv.

LECTURE II.

1. Introductory. 2. Extinction of Animals. 3. Law of Extinction. 4. Animals extirpated by Human Agency. 5. Apteryx and Notornis of New Zealand. 6. Moa of New Zealand. 7. Dodo of the Mauritius. 8. Irish Gigantic Deer. 9. Epoch of Terrestrial Mammalia. 10. Fossil Mammalian Remains. 11. Comparative Anatomy. 12. Osteology of the Carnivora. 13. Osteology of the Herbivora. 14. Dental organs of the Rodentia. 15. General Inferences. 16. Fossil Elephants, &c. 17. Fossil Mammalia of the valley of the Thames. 18. Fossil Elephants of other parts of England. 19. Extinct Elephant or Mammoth in Ice. 20. Mammoths of the alluvial deposits of Russia. 21. Siberia and Russia in the Mammoth-epoch. 22. Mastodon. 23. Mastodons of Ava. 24. Fossil Mammalia of the Sub-Himalayas. 25. Sub-Himalayan tertiary deposits. 26. Remarkable collocation of Fossil animals. 27. The Pampas. 28. The Sloth tribe. 29. Megatherium. 30. Mylodon. 31. Megalonyx. 32. Glyptodon. 33. Toxodon. 34. Fossil Hippopotamus, &c. 35. Dinotherium. 36. Fossil Carnivora in Caverns. 37. Cave of Gaylenreuth. 38. Förstershöhle, or Forest-cave. 39. Bone Caverns in England. 40. Diseased Bones found in Caverns. 41. Human Bones in Caverns. 42. Osseous Breccia. 43. The Rock of Gibraltar. 44. Osseous Breccia of Australia. 45. Retrospect.

1. Introductory.—In the previous Lecture we took a comprehensive view of the actual physical condition of the surface of our planet, and of the nature and effects of the principal agents by which the land is disintegrated and renewed. We found in the modern fluviatile and marine deposits, that the remains of man, of works of art, and of existing species of animals and vegetables were preserved. In every step of our progress, the grand law of nature, alternate decay and renovation, was exemplified in striking characters. Whether in the regions of eternal snow, or in torrid climes,—in the rocks and mountains, or in the verdant plains,—by the agency of heat, or by the effect of cold,—of drought, or of moisture,—of steam, or of vapour,—by the abrasion of torrents and rivers,—by inundations of the ocean, or by volcanic eruptions,—still the work of destruction, in every varying character, was apparent. And on the other

hand we perceived that, amidst all these processes of decay and desolation, perpetual renovation was going on; that Nature was repairing her ruins, and accumulating fresh materials for new islands and continents, and that innumerable living instruments were employed to consolidate and build up the rocky fabric of the earth; and that even the most terrific of physical phenomena, the earthquake and the volcano, were but salutary provisions of the Supreme Cause, by which the harmony and integrity of our planet were maintained and perpetuated.

The occurrence of human skeletons in modern limestone, of coins and works of art in recent breccia, and the preservation of the bones of existing species of animals, and of the leaves and branches of vegetables, in the various deposits that are in progress of formation, incontestably prove that enduring memorials of the present state of animated nature will be transmitted to future ages. When the beds of the existing seas shall be elevated above the waters, and covered with woods and forests,—when the deltas of our rivers shall be converted into fertile tracts, and become the sites of towns and cities,—we cannot doubt that, in the materials extracted for their edifices, the then existing races of mankind will discover indelible records of the physical history of our times, long after all traces of those stupendous works, upon which we vainly attempt to confer immortality, shall have disappeared.

But we must now proceed, and pass from the ephemeral productions of man to the enduring monuments of nature,—from the coins of brass and silver, to the imperishable medals on which the past events of the globe are inscribed,—from the mouldering ruins of temples and palaces, to the examination of the mighty relics which the ancient revolutions of the earth have entombed.

2. Extinction of animals.—Before we enter upon the geological history of the period immediately antecedent to

the present, it will be necessary to notice one of the most remarkable facts which modern investigations have demonstrated, namely, the annihilation of numerous species and genera of animals and plants.

From the continual transmutations in the distribution of land and water, to which the earth's surface has been subjected, as indicated by our previous remarks, the destruction of some forms of animal life would seem to be a probable, if not inevitable, result; and such proves to have been the case. But not only has the extinction of certain races taken place; a rigid examination of the fossil remains entombed in the various strata demonstrates that other species, suited to peculiar states of the earth, have successively appeared and played their part in the drama of life; and, when the physical conditions of the lands and waters were altered, so as to be no longer adapted for the continuance of those types of animated nature, they in turn passed away and were succeeded by new forms of organization.

The annihilation of whole tribes of animals and plants has no doubt depended on a variety of causes; and it is probable that in the earlier ages an important agent in the extinction of many species, both terrestrial and aquatic, was the frequent oscillation in the relative position of the land and sea, and the consequent variations in atmospheric condition.

3. LAW OF EXTINCTION. — But there is another consideration that bears upon this problem, and to which I must here briefly allude. It has been found that in countries where certain formations follow each other in tranquil and uninterrupted succession, the same restriction of particular fossils to special groups of strata, and the same disappearance of some species, and the first advent of others, as rigidly prevail as in England, where the strata have been subjected to violent and repeated physical revolutions.

This is remarkably the case in Russia, where the Silurian,

Devonian, Carboniferous, and Permian systems of rocks extend over immense regions, and are composed of horizontal deposits of different ages, nearly all conformable in position, and yet clearly separable from each other by mineral characters and organic remains. Here then is unequivocal proof, that some races of animals have disappeared and been succeeded by others over enormously extended areas in which there has never been any great physical catastrophe, nor the smallest eruption of plutonic or volcanic matter.*

These facts naturally suggest the inquiry, whether the continuance of species may not be governed by some natural law, in like manner as is the duration of the life of the individuals or any given species. May not some species, for example, be so constituted as to continue but for a few hundreds or thousands of years, and others for ages; while other organisms may be endowed with a perpetuity of reproduction through all time? In this view of the subject, species may have become extinct, simply because the predestined term for the persistence of that peculiar form of organism was expired; and this may have taken place without any necessary relation to surrounding physical conditions. In fine, may not the termination of the race, like the death of the individuals, be the natural and inevitable result of their organization?

4. ANIMALS EXTIRPATED BY HUMAN AGENCY.—But leaving for the present the further consideration of this difficult problem, we pass to the examination of the effects of human agency on the extinction of animals; and we shall find conclusive evidence, that, since Man became the lord of the creation, his necessities and caprice have occasioned the ex-

* "Geology of Russia," by Murchison, De Verneuil, and Keyserling. These highly interesting results of the labours of these eminent geologists have introduced a new and important element in all speculations relating to the cause of the extinction of species in the ancient periods.

tirpation of many species of animals, of which relics occur in the superficial alluvial deposits, associated with those of contemporary species, but concerning which both history and tradition are silent.

In this country, the beaver, wolf, hyena, bear, &c. are examples of animals which, though exterminated in these islands, still exist on the continent; while the mammoth and Irish gigantic deer, of which numerous remains are found in our alluvia and drift, have long since been obliterated from the face of the earth. That the gradual extinction of many of the existing species of animals will be effected by human agency alone cannot admit of question. In those animals which supply fur, a remarkable proof of the immense destruction which is carried on is stated in the American Journal of Science. "Immediately after South Georgia was explored by Captain Cook, in 1771, the Americans commenced carrying seal-skins from thence to China, where they obtained most exorbitant prices. *One million two hundred thousand skins* have been taken from that island alone, since that period; and nearly an equal number from the Island of Desolation! The numbers of the fur-seals killed in the South Shetland Isles (S. lat. 63°), in 1821 and 1822, amounted to three hundred and twenty thousand. This valuable animal is now almost extinct in all these islands." From the most authentic statements it appears certain that the fur-trade must henceforward decline, since the advanced state of geographical science shows that no new countries remain to be explored. In North America the animals are slowly decreasing from the persevering efforts, and the indiscriminate slaughter, practised by the hunters, and by the appropriation to the use of man of those forests and rivers which once afforded them food and protection. They recede with the aborigines before the tide of civilization.

Before we proceed further in this argument, it will be in-

teresting to notice a few of the links which connect the present "chain of being" with the past; — in other words, those species which are on the point of extinction, and others which have disappeared within a comparatively recent period.

5. THE APTERYX (*wingless bird*) AND NOTORNIS (*southern bird*) OF NEW ZEALAND.—The Apteryx, a bird peculiar to New Zealand, and belonging to a very limited group, of which the Ostrich is a well-known type, appears to be rapidly approaching extinction. The best known species is of the size of a small turkey, of a chestnut brown colour, the feathers being long, lanceolate, and hair-like as in the Emu, but each plume has but a single shaft. It has a slightly-curved bill, with

LIGN. 16.—THE APTERYX OF NEW ZEALAND.

the nasal apertures at the base, as in birds with a similar conformation of beak, which is adapted for respiration while immersed in mud or water. It has no visible wings; and in the skeleton the bones of the anterior extremities are but very little developed. Its habits are nocturnal, and it feeds on worms and insects. It is very difficult to be obtained, and is hunted by torch-light by the natives for the sake of its skin, which is highly prized to ornament the dresses of their chiefs. It has become very rare, and must soon be

exterminated, for its numbers are fast diminishing.* The Notornis† is a short-winged rail, first known by fossil bones, found in the sands and volcanic debris at Waingongoro, North Island, by Mr. Walter Mantell, and determined by Professor Owen. A living specimen was subsequently caught and eaten by some sealers on the Middle Island, but the skin was fortunately obtained by Mr. Mantell. The natives had a tradition of the existence of this water-rail (called Takahé), but believed it to be extinct. The specimen above alluded to is figured in the Frontispiece of the "Petrifactions." There are now two specimens known; both are in the British Museum.

6. THE MOA OF NEW ZEALAND (*Dinornis* of Professor Owen).—About eighteen years since a portion of a femur (thigh-bone) of large size was brought from New Zealand, and submitted to the examination of Professor Owen, who pronounced it to belong to a gigantic bird of the same family as the Apteryx. Subsequent discoveries have proved the correctness of this inference; and the numerous bones since received establish the former existence in the islands of New Zealand, at no very recent period, of several species of a tridactyle bird, resembling the Apteryx in its general conformation, but in some cases one-third larger than the African Ostrich. These bones have been found in the swamps and other alluvial deposits of the Middle Island, and in sand-hills and in caves in the North Island.

It is remarkable that these bones were referred by the natives to a gigantic bird, which they deemed sacred, and called MOA, before these relics had been examined by any European, and when the living New Zealanders could not have known of the existence of a bird larger than their own

* See Trans. Zool. Soc. of London, vol. ii.; and Petrifactions and their Teachings, or Fossils of the British Museum, p. 106.

† Zoological Transact. vol. iii. and Petrifactions, p. 125.

Apteryx. The native traditions assert the former abundance of these birds, and the existence of the race at the present time within hallowed and not to be violated precincts is still believed. Not only from the state of the bones, which have been found bearing the mark of edged tools, and mixed with human bones in the ash-heaps of ancient feasts, but also from the allusions in the native songs and tales to the gigantic bird and its flowing plumes, it is probable that the Moa (if extinct) was exterminated, like the Irish gigantic Deer and the Dodo, by the agency of man.

The bones hitherto sent to this country belong to numerous individuals, and are referable to seven or more species, materially differing from each other in size.*

Thus we have certain evidence that the Islands of New Zealand (which are situated between the 30th and 50th degrees of south latitude, and are about 900 miles in length) were inhabited, at no very remote period, by numerous species of wingless birds, some of much greater magnitude than any now known to exist; that these are extinct, and but two diminutive types of this wingless race, the Apteryx and Notornis, remain; the former, in all probability, is destined to be speedily exterminated; and of the latter two specimens only are known to exist.

7. The Dodo (*Didus ineptus*).—A remarkable instance of the extirpation of a very peculiar type of organization is afforded by the Dodo, which has been annihilated, and become a denizen of the fossil kingdom, almost before our eyes. The Dodo was a terrestrial bird, probably of the pigeon-family, larger than a turkey, of a dun colour on the back, and marked on the breast like a cock pheasant; it abounded in

* For a full account of the Moa, see Professor Owen's Memoirs in the Zoological Transactions; also Petrifactions and their Teachings, p. 93; and Pictorial Atlas, p. 172, and Frontispiece. A perfect skeleton of *Dinornis elephantopus* has lately been set up in the Paleontological Gallery of the British Museum.

the Mauritius and adjacent islands. When those countries were first colonized by the Dutch, little more than two centuries ago, the Dodo formed the principal food of the in-

LIGN. 17.—THE DODO.
(From a Painting in the British Museum.)

habitants; but, as it unfortunately proved to be incapable of domestication, its numbers were soon diminished, and the species insensibly disappeared. A live Dodo was exhibited in London in 1638 as a great curiosity; and stuffed specimens were preserved in the various museums of Europe: paintings of the living animal are still extant in the Ashmolean Museum at Oxford, and in the British Museum (see *Lign.* 17). But the Dodo is now extinct; it is no longer to be found in the isles where it once flourished, and even all the stuffed specimens are destroyed. Nearly the only known relics that remain, are the head and foot of an individual in the Ashmolean, the leg of another in the British Museum, a skull in the museum at Copenhagen, and an upper mandible at Prague. To render this illustration complete, some bones of the Dodo have been found in a tufaceous deposit, beneath a bed of lava, in the Isle of France, and in a cave in

the Isle of Rodriguez; so that, if the figures and remains of the recent birds above mentioned had not been preserved, these fossils would have constituted the only proof that such creatures had ever existed.*

We pass on to the consideration of the extinct mammalia.

8. The Irish gigantic Deer† (*Cervus megaceros*, or Deer with great antlers‡). The shell-marls of Ireland contain the bones of an animal which, like the Dodo, was once contemporary with the human species, but is now extinct: the last individuals of the race having, in all probability, been destroyed by man. These remains commonly occur in the beds of marl beneath the peat-bogs, which are apparently, like those of Scotland, the sites of ancient lakes and bays. In Curragh, immense quantities of these bones lie within a small space: the skeletons appear to be entire, and are found with the skull elevated, and the antlers thrown back on the shoulders, as if a small herd of these great Deer had sought for refuge in the marshes, and had sunk into the morass and been suffocated. Remains of this Deer occur also in marl and gravel, in the Isle of Man and in many parts of England, France, Germany, and Italy, associated with recent species of river-shells.

This extinct creature far exceeded in magnitude any living species of deer. The skeleton is upwards of ten feet high from the ground to the highest point of the antlers, which are palmated, and are from ten to fourteen feet from one extremity to the other.‖ Skulls have been found without horns, and are supposed to have belonged to females. The average

* See an interesting article on the Dodo in the Penny Cyclopedia; and Strickland and Melville's admirable Monograph, 1848.

† Formerly and incorrectly termed Elk.

‡ Owen's British Fossil Mammalia, p. 444; Pictorial Atlas, pl. 71; fig. 2.

‖ There is a fine skeleton of the gigantic Deer in the British Museum, and another in the Hunterian Museum.

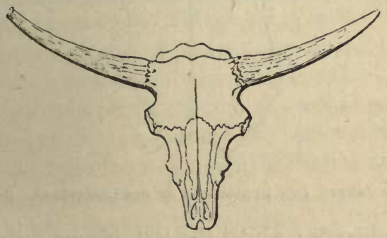
weight of the skull and antlers is about seventy-five pounds. The bones are generally in a fine state of preservation, of a dark-brown colour, with here and there a bluish incrustation of phosphate of iron, like those of the deer from Lewes Levels. In some instances they are in such a state of preservation that the medullary cavities contain marrow having the appearance of fresh suet, and which burns on the application of a lighted taper. This Deer shed its horns, and probably, like existing species, annually. The researches and observations of Professor Jameson, Mr. Weaver, and others have rendered it highly probable that this majestic creature was coeval with man. A skull was discovered in Germany, associated with urns and stone hatchets; and in the county of Cork, a human body was exhumed from a wet and marshy soil, beneath a bed of peat eleven feet thick; the body was in good preservation, and enveloped in a deer-skin covered with hair, which appeared to be that of the gigantic Deer. A rib of this animal has been found in which there is a perforation evidently occasioned by a pointed instrument while the creature was alive; for there is an effusion of callus or new bony matter, which could only have resulted from something remaining in the wound for a considerable period; such an effect, indeed, as would be produced by the head of an arrow or spear; though possibly the wound might have been inflicted by the antler of another stag. There is, therefore, presumptive evidence that the last individuals of the race were extirpated by the hunter-tribes who first took possession of these islands.*

Beds of gravel and sand, containing recent species of marine shells with bones of the Irish Deer, have been observed by Dr. Scouler in the vicinity of Dublin at an elevation of

* See a most interesting paper in the proceedings of the Yorkshire Geological and Polytechnic Society, for 1855, by Mr. H. Denny, "on the claims of the gigantic Irish Deer to be considered as contemporary with man."

two hundred feet above the level of the sea. This extinct quadruped, though found in peat-bogs and morasses of comparatively very recent date, must therefore have been an inhabitant of Ireland antecedently to some of the last changes in the relative position of the land and water. The discovery of a vast number of skeletons in the small area of the Isle of Man seems to indicate a great alteration in the extent of land and sea; for it is difficult to conceive that such herds of this gigantic race could exist in so limited a district. It is therefore probable that the island was separated from the mainland at no remote geological period, by subsidences commensurate with the elevations of which Ireland affords such decisive evidence.*

The Ox-tribe also affords interesting examples of the diminution or total passing away of species from the European area within comparatively modern times. Of the four species known as occurring fossil in the post-tertiary deposits of Britain, namely, 1. the *Bison priscus* (or old bison), 2.



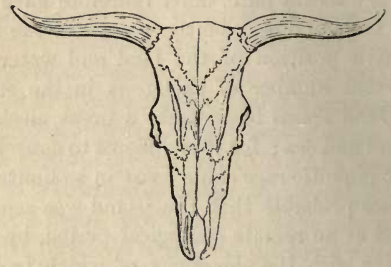
LIGN. 18. SKULL AND HORN-CORES OF BISON PRISCUS. Front view.

Bos primigenius (ancient ox), 3. *Bos longifrons* (long-fronted ox), and 4. *Bubalus moschatus* (musk-buffalo),† the first is

* See also Cumming, Geol. Journ. vol. x. p. 215.

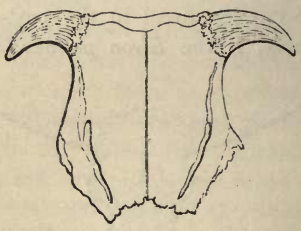
† In the Quart. Geol. Journ. vol. xii. p. 124, Prof. Owen has described a skull of this animal, found in the gravel of the Thames valley at Maidenhead. Two other skulls have been lately discovered in the gravel of the Avon valley, south of Bath; and a fourth fossil skull is preserved in the Museum at Berlin.

now represented by the herd of Aurochs preserved in the royal forests of Lithuania; the second, though apparently



LIGN. 19. SKULL AND HORN-CORES OF BOS PRIMIGENIUS. Front view.

well known to the Romans, is now quite extinct; the third survives probably in the race of short-horned cattle of Wales



LIGN. 20. SKULL AND HORN-CORES OF BOS LONGIFRONS. Front view.

and the Highlands; whilst the last is now restricted to the frozen arctic regions of the north.*

In the examples above described, we have an interesting transition from the living to the lost types of animal existence. 1st, Species no longer inhabitants of the British islands, but still living in other countries; 2ndly, Animals which have been exterminated within the last few centuries;

* Prof. Owen's Brit. Foss. Mammals, p. 540, and Lecture on Ruminants, &c. to the Royal Institution, May 2nd, 1856.

lastly, Species that have been utterly destroyed by the early races of mankind.*

9. Epoch of terrestrial mammalia.—We must now advance another step in the history of the past, and proceed to the consideration of the geological phenomena presented by the period immediately antecedent to the present, when vast regions were inhabited by large herbivorous mammalia, with which species of existing races were associated. Thus while the present may be termed the *Modern* or *Human Epoch*, that which forms the immediate subject of investigation may be designated the *Epoch of terrestrial mammalia.*

"When the traveller," says Cuvier, "passes over those fertile plains, where the peaceful waters preserve, by their regular course, an abundant vegetation, and the soil of which is crowded by an extensive population, and enriched by flourishing cities, which are never disturbed but by the ravages of war or the oppression of despotism, he is not inclined to believe that nature has also had her intestine wars, and that the surface of the globe has been overthrown by various revolutions and catastrophes. But his opinions change as he penetrates into that soil at present so peaceful; or as he ascends the hills which bound the plains. His ideas expand, as it were, with the prospect; and as soon as he ascends the more elevated chains, or follows the beds of those torrents which descend from their summits, he begins to comprehend the extent and grandeur of the physical events of ages long past. Or if he examines the quarries on the sides of the hills, or the cliffs which form the boundaries of the ocean, he there sees, in the displacement and contortion of the strata, and in the layers of water-worn materials, teeming

* Man himself supplies striking instances of the disappearance of distinct races and varieties from the face of the earth, chiefly through the agency of his fellows. The natives of Van Diemen's Land are amongst the latest examples of this decadence of a type, for they are either quite extinct, or are represented by a solitary individual.

with the remains of animals and plants, proofs that those tranquil plains, those smooth unbroken downs, have once been at the bottom of the deep, and have been lifted up from the bosom of the waters; and everywhere he will find evidence that the sea and the land have continually changed their place."*

In almost every part of the world, beneath the modern alluvial soil, extensive beds of gravel, clay, and loam are found spread over the plains, or on the flanks of the mountain-chains, or on the crests of ranges of low elevation; and in these accumulations of marine and fluviatile debris, are imbedded immense quantities of the bones of large mammalia. These belong principally to animals related to the elephant, as the mammoth, mastodon, &c., and to species of hippopotamus, rhinoceros, horse, ox, deer, &c.; and some are referable to extinct genera; while in caverns and fissures of rocks, more or less filled with loam and breccia, bones of tigers, boars, hyenas, and other carnivora occur. Fossils of this kind exist in great abundance in various parts of Europe, Asia, and America; they are found alike in the tropical regions of India, and in the frozen plains of Siberia; and there are but few considerable districts in Great Britain in which some vestiges of this kind do not occur.

10. FOSSIL MAMMALIAN REMAINS.—For the convenience of study, Dr. Buckland classes these remains under five heads, namely:—

First. Bones of land-animals, that were drifted into estuaries, and sometimes associated with marine shells; such as those found in the Sub-Apennine formations; and in the beds of gravel, sand, &c. provincially termed *Crag*, in Norfolk and Suffolk; in loam and chalk-conglomerate in the cliffs of Kent and Sussex; and in clay off Harwich and Herne Bay.

Secondly. Terrestrial quadrupeds, imbedded with fresh-

* "Discours sur les Révolutions de la Surface du Globe."

water shells, in strata that have been formed, during the same epoch as the above, at the bottom of fresh-water lakes and in the beds of rivers and deltas; such are the fossil bones of the lacustrine marls of the Val d'Arno, those in the valley of the Thames, &c.

Thirdly. Similar remains in superficial drift spread over the surface of rocks of all ages; as in beds of gravel near London; Petteridge Common in Surrey, &c.

Fourthly. Bones of carnivorous and herbivorous animals accumulated in caverns and fissures of rocks during the later period of the same epoch. The caves of Gaylenreuth, Kirkdale, Kent's Hole near Torquay, &c., are examples.

Lastly. Osseous breccias that occur in fissures of limestone on the shores of the Mediterranean, in the Ionian Isles, in the rock of Gibraltar, at Plymouth, in the Mendip Hills, &c.*

Before directing your attention to the fossils before us, which are from alluvial deposits of various ages and from different localities, it will be necessary to review the leading principles of the science which treats of the structure of organized beings. Thus, while in the preceding lecture we referred to Astronomy to dissipate the obscurity which shrouded the earliest physical condition of our planet, we are now led to that important department of natural knowledge termed *Comparative Anatomy*, to enable us to determine the extinct forms of animal existence. I shall therefore explain the mode of induction employed by the scientific observer in the investigation of the fossil remains of animals, and by which he is enabled to ascertain the structure and economy of creatures which have long since disappeared from the face of the earth.

11. Comparative anatomy.—To a person uninstructed

* Dr. Buckland's Bridgewater Essay, p. 94.

in anatomical details, the specimens before us would appear a confused medley of bones, and of osseous fragments impacted in solid stone; and the only knowledge he could derive from their examination would be the fact, that the stone was once in the state of sand or mud, in which, while soft, the bones had become imbedded. But in vain would he seek for further information from these precious historical monuments of Nature; to him they would prove as unintelligible as were the hieroglyphics of Egypt, before Young and Champollion explained their mysterious import. It is only by an acquaintance with the structure of the living forms around us, and by acquiring an intimate knowledge of their osseous framework or skeleton, that we can hope to decipher the handwriting on the rock, obtain a clue to guide us through the labyrinth of fossil anatomy, and conduct to those interesting results, which the genius of the immortal Cuvier first taught us how to acquire. And here it will be necessary to enter upon the consideration of those admirable principles of the correlation of structure in organized beings, that were first announced by that illustrious philosopher, and which form the basis of all palæontological knowledge.

The organs of every animal, observes Cuvier, must be regarded as forming a machine, the parts of which are mutually dependent on each other, and exquisitely adapted for the functions they are destined to perform; and such is the intimate relation of the several organs, that any variation in one part is constantly accompanied by a corresponding modification in another. This correlation, or mutual adaptation of the several parts of the animal fabric, is a law of organic structure, which, like every other induction of physical truth, has only been established by patient and laborious investigation. It is by the knowledge of this law that we are enabled to reassemble, as it were, the scattered remains of the beings of a former state of the globe,—to determine their place in the scale of animated nature,—and to reason

on their organization, habits, and economy, with as much clearness and certainty as if they were still living and before us.

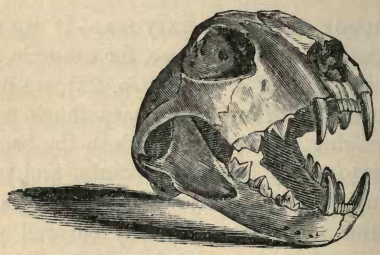
I will demonstrate this proposition by a few examples. Of all the solid parts of the animal frame the most obviously mechanical are the jaws and teeth; and, as we know in each instance the offices they are intended to perform, these organs afford the most simple and striking illustration of the principles above enunciated.

LIGN. 21.—SKULL OF THE BENGAL TIGER.
(Felis tigris.)

12. OSTEOLOGY OF THE CARNIVORA.—If we examine the jaws of the skulls before us, those, for example, of a Bengal Tiger (*Lign.* 21) and of a Cat (*Lign.* 22), we perceive that there are cutting teeth in front, sharp fangs on the sides, and molar, bruising, or crushing teeth in the back part. The molars rise into sharp lanciform points, and overlap each other in the upper and lower jaw, like the edges of a pair of shears; and the teeth are externally covered with a thick crust of enamel. This is evidently an apparatus for tearing and cutting flesh, or for cracking bones; but is not suited for grinding the stalks or seeds of vegetables. The jaws fit together by a transverse process or joint, which moves in a corresponding depression in the skull, like a hinge; they open and shut like shears, but admit of no grinding motion; this, then, is such an articulation as is adapted for a carnivorous animal; and every part of this instrument is admirably fitted for its office.

But all these exquisite adjustments would be lost, were there not levers and muscles to work the jaws,—were not each portion of the animal frame adapted to all the other parts,—and were not the instincts and appetites of the animal such as are calculated to give to this apparatus its appropriate movements.

Let us reverse the order of the argument,—let us assume that the stomach of an animal be so organized as to be fitted for the digestion of flesh only, and that flesh recent,—we should find that its jaws would be so constructed as to fit them for devouring live prey,—the claws for seizing and tearing it,—the teeth for cutting and dividing it,—the whole system of its powers of motion for pursuing and overtaking it,—the organs of sense for discovering it at a distance,—and the brain endowed with the instinct necessary for teaching the animal how to conceal itself, and lay snares for its victims. Such are the general relations of the structure of

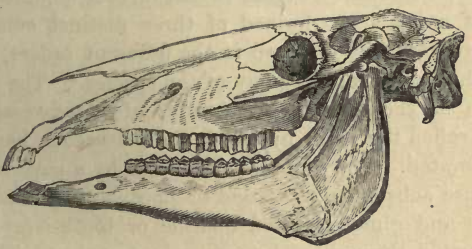


LIGN. 22.—SKULL OF A WILD CAT.
(Felis Canadensis.)

carnivorous animals, and which every being of this class must indispensably combine in its constitution, or its race cannot exist. But subordinate to these principles, are others connected with the nature and habits of the prey upon which the animal is intended to subsist, and thence

result modifications of the details in the forms which arise from the general conditions. Thus, in order that the animal may have the power requisite to carry off its prey, there must be a certain degree of vigour in the muscles which elevate the head; and thence results a determinate form in the vertebræ or bones from which these muscles originate, and in the back of the skull in which they are inserted. That the paws may be able to seize their prey, there must be a certain degree of mobility in the toes, and of strength in the claws, and a corresponding form in all the bones and muscles of the foot. It is unnecessary to extend these remarks, for it will easily be seen that similar conclusions may be drawn with regard to all the other parts of the animal.* In the Tiger and the Cat (*Ligns* 21, 22) we have a familiar illustration of what has been advanced.

13. OSTEOLOGY OF THE HERBIVORA. — In animals which are destined to live on vegetables we have the same mutual relations; the sharp fangs of the teeth are wanting; the



LIGN. 23.—SKULL OF THE HORSE
(Equus Caballus.)

enamel is not all placed on the top of the teeth, as in the carnivora, but arranged in deep vertical layers, alternating

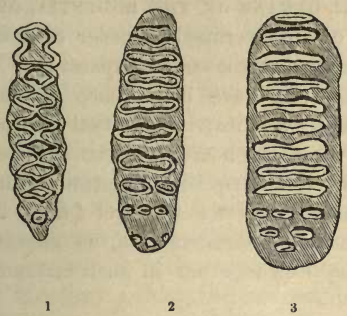
* Consult Cuvier's "Discours sur les Révolutions;" "Leçons d'Anatomie Comparative;" "Ossemens Fossiles," &c.

with bony matter; and this arrangement secures, in all states of the teeth, a rough grinding surface, as in the horse and the elephant. The flat molar teeth are not formed for cutting, but for mastication, and the jaws are loosely articulated together, so as to allow of a grinding movement; had the socket and corresponding part of the jaw been the same as in the tiger, the teeth could not have performed their office; in the skull of the horse (*Lign.* 23), this modification of structure is exemplified. Again, I might proceed in the argument, and show the adaptation of the muscles of the head to the apparatus here described; and, beginning with the jaw, review the whole animal frame, and demonstrate how all its parts are alike wonderfully constructed and fitted together, to perform the functions necessary for the being to which it belongs.

In the Elephant, which has but four teeth in each jaw, the deficiency of prehensile incisor teeth being supplied by that wonderful instrument, the proboscis or trunk, the structure of the dental organs is still further modified. The teeth of animals are formed of three distinct substances, which are variously disposed in the different orders, according to the habits and economy of the species.* The nucleus or germ of the tooth is a congeries of blood-vessels and nerves, called the *pulp*, by which the calcareous hard parts are elaborated. The pulp is surrounded by a covering of a very dense substance, composed of phosphate of lime, with albumen and gluten, termed dentine or tooth-ivory, which is permeated throughout by very minute tubes. The dentine is encased in a still harder material, called *enamel.* In the teeth of man, and of the carnivora, the enamel covers the entire external surface of the crown. There is a third substance, a coarse kind of dentine, of an opaque and yellowish appearance, termed *crusta petrosa*, or cement, which, in the elephant and other herbivora, is interstratified with the

* See Owen's "Odontography."

enamel and dentine. The intermixture of these three dental elements—the tooth-ivory, cement, and enamel—is apparent on the worn surfaces of the teeth of elephants; and it differs in the several recent and fossil species.*



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LIGN. 24.—GRINDING SURFACE OF TEETH OF ELEPHANTS.

Fig. 1. The worn surface of the crown of a tooth of the African Elephant. Fig. 2. Grinding surface of a tooth of the Mammoth (Elephas primigenius). Fig. 3. Grinding surface of the Asiatic Elephant.

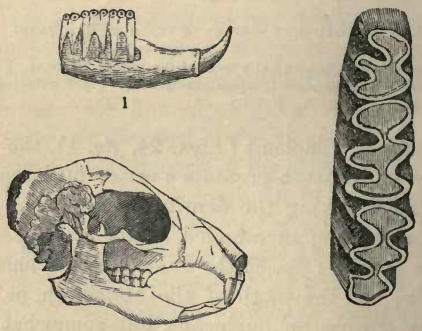
In the African Elephant (*Lign.* 24, *fig.* 1), the worn surface of the molar teeth presents a series of lozenge-shaped lines of enamel, having the dentine on the inner margin of the ridges, and being surrounded by the *crusta petrosa.* In the Asiatic species (*fig.* 3) the enamel forms narrow transverse bands; and the tooth of the Mammoth, or fossil elephant (*fig.* 2), has an analogous, but somewhat different, distribution.

The appearances shown in these horizontal sections of the crown of the teeth arise from the dentine being disposed in parallel and vertical plates which have an immediate investment of enamel, and are bound together by an external layer of cement that envelopes the entire series, which often

* See "Medals of Creation," vol. ii. p. 793; "Teeth of Mammalia."

consists of from twenty to thirty plates. By this peculiar modification of structure, a rough grinding surface, adapted for the mastication of vegetable food, is always maintained, from the unequal wearing away of substances of such different degrees of hardness.

14. DENTAL ORGANS OF THE RODENTIA, OR GNAWERS.—In the jaws of an intermediate order of animals, we find new modifications of the same apparatus. Thus the *Rodentia*, or gnawers, have long sharp cutting teeth, like nippers; it is by these instruments that the rat can speedily gnaw a hole through a board, and the squirrel in a nut, in consequence of their exquisite adaptation for these operations. In the skull of the Squirrel (*Lign.* 25, *fig.* 2) the front teeth are of enormous size, as compared with the molar, and they lock together in such manner as to render



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LIGN. 25.—SKULL AND TEETH OF RODENTIA, OR GNAWERS.

Fig 1. Inner side of the left lower jaw of a Florida Rat (Arvicola Floridana), of the natural size.
2. Skull of the Squirrel (Sciurus).
3. Molar teeth of the upper jaw of a Florida Rat, magnified; seen obliquely.

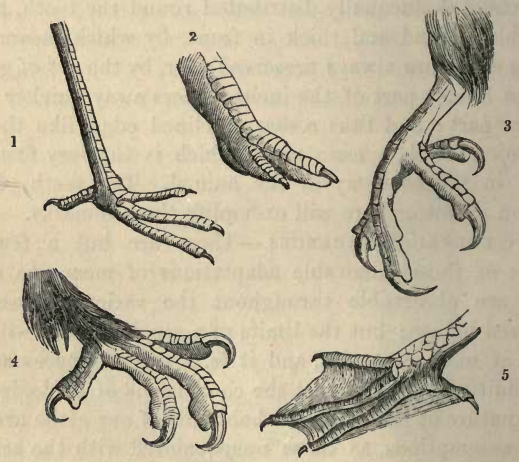
a grinding movement impossible; a corresponding adjustment, therefore, takes place,—the lower jaw is so construct-

ed as to work in the skull neither in a transverse nor in a rotatory direction, but lengthwise, like the action of a carpenter using his plane, the teeth moving backwards and forwards; as may be observed in the rabbit while eating its food. The enamel of the molar teeth, as for example in those of the rat (see *Lign.* 22, *fig.* 3), is placed vertically and transverse to the jaw, so as to form an admirable grinding surface. But this is not the only variation of structure observable in these teeth. The incisors, being implements of constant use, are renewed by continual growth; and there is a special provision for their support in a bent socket. The enamel is unequally distributed round the tooth, being very thin behind and thick in front, by which means the cutting edges are always preserved; for, by the act of gnawing, the hinder part of the incisor wears away quicker than the fore part; and thus a sharp inclined edge, like that of an adze or chisel, is maintained, which is the very form required in the economy of the animal. The teeth of the common rabbit or hare will exemplify these remarks.

15. GENERAL INFERENCES.—These are but a few instances of those admirable adaptations of means to ends, which are observable throughout the various classes of organized beings: but the limits of a single lecture will not admit of more examples, and it is, I trust, unnecessary to offer additional proofs, that the conclusions of geologists as to the nature of the ancient inhabitants of our globe are not vague assumptions, as those unacquainted with the science might suppose, but the legitimate deductions of laborious and patient investigations. A few teeth and bones—sometimes but a single relic of this kind—are the elements by which the palæontologist is enabled, not only to restore the forms of creatures now banished from the face of the earth, but also to ascertain their habits and economy, and even arrive at positive conclusions respecting the nature of the country of which they were once the inhabitants. If we

find the remains of animals which were herbivorous, it follows that there must have been a condition of nature calculated for the growth of vegetable productions for their subsistence; a suitable soil and climate, and a country diversified by hills, valleys, and plains, with streams and rivers to carry off the superfluous waters.

The same laws, under certain modifications, apply to other classes of beings. In birds, the form of the feet is modified according to the habits of the different orders. In the parrot (*Lign.* 23. *fig.* 3), the claws are adapted to climb trees and to perch on the branches; but in the eagle



LIGN. 23.—DIFFERENT FORMS OF FEET IN BIRDS.

Fig. 1. Foot of the Heron; Fig. 2. of the Ostrich; Fig. 3. of the Parrot; Fig. 4. of the Eagle; Fig. 5. of the Pelican.

they are widely different, for its talons are constructed to lacerate and tear its prey (*fig.* 4). The feet of aquatic birds are formed like a paddle or oar, to enable them to make their way through the water (*fig.* 5); those of birds

that frequent marshes have a great expansion, like a tripod, that they may move over the unstable surface of the morass (*fig.* 1); while in species destined to inhabit sandy deserts, as the ostrich (*fig.* 2), the feet present a corresponding modification of structure.

We perceive, therefore, that every vertebrated animal has a solid and durable skeleton, or osseous support, formed upon one general plan, but modified in almost endless variety, in the relative magnitude, situation, and aspect of the different parts, so as to adapt itself to the various habits and functions of the diversified forms of animal life. In short, the Author of nature has by these changes varied the same general fabric in innumerable ways, bestowed upon it a thousand different instincts and passions, and adapted it to every element and climate, and to every possible variety of food and mode of existence; and it is by a profound knowledge of these principles of the correlation of the different parts of every organized creature, that the scientific observer is enabled to reconstruct the forms of extinct animals.

We may now enter upon that department of geology called *Palæontology*, or the science which treats of the fossil remains of the beings which inhabited our planet in former ages.

16. Fossil Elephants, &c.—As the bones and teeth are the least perishable parts of the animal structure, they are in general the only indications of the characters of the ancient mammalia. Occasionally very delicate parts, such as the tunic of the eye, the membranes of the stomach, the hair and integuments of the skin, &c., are preserved in a fossil state, examples of which we shall hereafter adduce. In the older rocks, the bones are generally mineralized, and no longer possess the white and glossy appearance of the recent skeleton; but those which occur in superficial gravel, and in caverns, are commonly of a porous and earthy

character, like bones that have lost a portion of their animal matter by being buried in a dry and loose soil.

The fossil bones and teeth we have now to examine are separable into two classes, namely, those which occur in the gravel, marl, &c., of the drift and alluvial deposits, and those buried in fissures and caverns. The former are principally referable to herbivorous pachyderms and ruminants; the latter to carnivora.

I will first take a brief review of the remains of the large herbivora, especially of those allied to the elephantine family, which occur in great abundance, and are very generally distributed throughout Europe, Asia, and America. In the earlier ages, these colossal bones were supposed to belong to gigantic races of mankind, and gave rise to the marvellous traditions of giants, so rife in every country in Europe; but we need not smile at the ignorance and credulity of our ancestors, for, not many years since, a fossil tooth of an elephant, found in digging a well in Brighton, was supposed to be a petrified cauliflower!

In Russia, and more especially in Siberia, the fossil bones of extinct species of elephants and other mammalia are found throughout all the low lands, and in the sandy plains which extend from the borders of Europe to the nearest extreme point of America, and south and north from the base of the mountains of central Asia to the shores of the Arctic Sea. Within this space, which is almost equal in extent to the whole of Europe, fossil ivory is everywhere to be found; and the tusks are so numerous and well preserved, especially in Northern Russia, that thousands have been annually collected as a lucrative article of commerce. In Siberia alone, the remains of a greater number of elephants have been discovered, than are supposed to exist at the present time all over the world.*

* In 1844, a company of merchants was formed to collect teeth and tusks of mammoths from Siberia; for the fossil ivory was found to pos-

17. Fossil mammalia of the valley of the Thames.—It may appear astounding to some of my readers to treat of elephants, rhinoceroses, hippopotami, and gigantic deer, as having formerly inhabited the country irrigated by the Thames; yet such was unquestionably the case at no very remote epoch, when the land of England was united to the Continent, and the river extended over a much larger area than it has occupied since many centuries before the Roman advent. See Mr. Trimmer's Map, Quart. Geol. Journ. vol. ix. pl. 13.

The banks of the Thames, and of its tributary streams, are in great part composed of an ancient alluvial silt or brick-earth, many yards in thickness, containing, in certain localities, mammalian bones in considerable abundance, with interspersions of existing species of land and river shells.* At Erith this deposit reaches to 40 feet above the river, and near Maidstone to 60 feet.

At Grays in Essex (opposite Gravesend) these deposits may be seen to advantage in sections exposed in the extensive brick-fields. The beds consist of—1. Gravel and sand; 2. Loamy sand and brick-earth; 3. Ferruginous sand, shells, and gravel; 4. The chalk, which forms the foundation-rock of the country. From this locality alone have been obtained numerous bones of the elephant, rhinoceros, hippopotamus, horse, ox, stag, gigantic deer, vole, bear, hyena, and monkey.

sess all the qualities of the recent, and was said to be less liable to turn yellow. During the year, sixteen thousand pounds of teeth and tusks of mammoths were obtained, and these were sold at St Petersburg, under the denomination of Siberian ivory, at prices from 30 to 100 per cent. above those of recent elephantine ivory.

* There are also a species of *Cyrena*, supposed to be identical with one that now exists near Alexandria, and a *Unio*, of which the analogue lives in the lakes and rivers of Auvergne: neither are known as living British species. See a highly interesting memoir on these deposits, and their fossil remains, by John Morris, F.G.S. (of Kensington), author of "A Catalogue of British Fossils," &c.; Mag. Nat. Hist. vol. ii. p. 539.

Scarcely any traces of trees or plants have been met with, yet it is obvious that the country which supported these large herbivora must have had an abundant vegetation.*

18. FOSSIL ELEPHANTS OF OTHER PARTS OF ENGLAND.—Along the eastern coast of England, and off the mouth of the Thames, teeth, tusks, and bones of elephants and other mammalia are often dredged up by the fishermen, having been, for the most part, washed out of the alluvial deposits of the neighbouring cliffs by the action of the sea; for the same kind of drift or alluvial detritus is spread over the country along the maritime districts of Essex, Suffolk, Norfolk, and Yorkshire; and probably forms portions of the sea-bed also.

At Herne Bay, in the embouchure of the Thames, great numbers of mammalian bones have been found; Walton † in Essex is still more prolific; and the late Mr. Woodward informed me, that the elephants' teeth which had come under his observation from the coast of Norfolk must have belonged to more than 500 individuals.

On the western coast of Sussex, and in the neighbourhood of Arundel, Patcham, and Brighton, teeth and bones of elephants have at different times been exhumed. At Brighton the teeth are found in a deposit of rubbly materials, consisting of loam, chalk, and broken flints, resting on a bed of shingle covering the chalk.‡ In this old shingle-bed also bones and teeth of extinct species of elephant, ox, deer, horse, and bones of a whale,§ occur, and are associated in some instances with marine shells; similar fossils are

* At Ilford, in Essex, quantities of bones and teeth of elephants, rhinoceroses, hippopotami, ox, deer, &c., have been dug up. Mr. Baber of Knightsbridge has a very fine collection of these remains.

† On the sea-shore near Walton on the Naze there is said to be a thick layer of a white calcareous conglomerate, which is wholly composed of the detritus of elephants' bones.

‡ See above, p. 113, and Geology of the South-East of England, p. 32.

§ See Medals of Creation, vol. ii. p. 778, for an account of the discovery of the fossil jaw of a whale in Brighton cliffs.

found in deposits of a like character along the opposite coast of France.

These elephantine remains are, in the opinion of Dr. Falconer, referable to three or four species: but the greater number belong to the Mammoth, or fossil Elephant of Siberia.

With these relics of extinct mammalia are found those of genera and species which still inhabit England, as the badger, otter, polecat, weasel; and of others which were contemporary with the earliest British tribes, as the Irish gigantic deer, bear, beaver, wolf,* but have been exterminated by human agency, probably during the last 2000 or 3000 years.

19. Extinct Elephant, or Mammoth,† in ice.—There are but two species of existing elephants, namely, the African, which ranges as far south as the Cape of Good Hope, and the Asiatic, which is limited to within 30° north latitude. Yet the remains not only of one but of several extinct species of this family occur all over Europe and North America, and are imbedded in frozen gravel and drift in 72° north latitude. They even abound in ice-cliffs on the north-west angle of the American continent, near to Behring's Straits.

The occurrence of innumerable relics of huge extinct herbivorous mammalia over vast regions of the icy zone, where but few forms of animal life can now subsist, is a fact of so much interest in every point of view, as to demand our earnest attention. For not only are the bones and tusks found in a beautiful state of preservation, but sometimes even the entire body of the animal, with the flesh and skin, as fresh as if but recently imbedded.‡

* In the fenny district of Cambridgeshire, these and other mammalian remains have been found. See Professor Owen's History of British Fossil Mammals; and Medals of Creation, vol. ii.

† A Russian term applied to the fossil elephant.

‡ The entire carcasses of whales are occasionally discovered imbedded

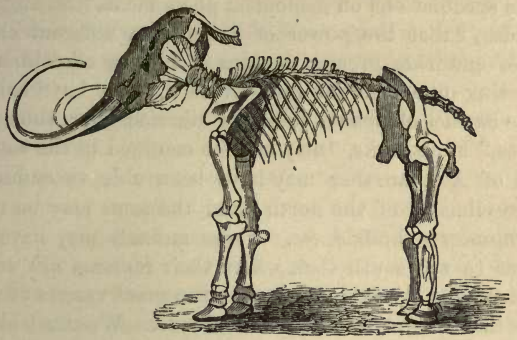
In 1774, near Vilhoui, the carcass of a rhinoceros was dug out of the frozen sand, where it must have been concealed for ages, the soil of that region being now always frozen to within a few inches of the surface. This specimen was a complete natural mummy, part of the skin being still covered with long hairs, and forming a warmer covering than that of the African rhinoceros.

The discovery of a mammoth under similar circumstances is yet more interesting.* Towards the close of the last century, 1799, a Tungusian fisherman observed in a cliff of ice and gravel, on the banks of the river Lena, a shapeless mass, the nature of which he was unable to determine. In the course of the next year it was more visible, and on the third a large tusk was seen projecting from the ice-cliff, and at length became detached. On the fifth year, an early thaw set in, and the entire carcass of a mammoth was exposed, and at length fell upon the ground. It was twelve feet high, and about sixteen feet in length; the tusks were nine feet long. The flesh was in such a state of preservation, that it was devoured as it lay by wolves and bears, and the hunters fed their dogs with the remains. The skin was covered with a hairy coat consisting of black bristles, thicker than horsehair, and fifteen inches in length, of wool of a reddish brown, and hair of a fawn colour; and there was a mane on the neck. Upwards of 30 lbs. of hair were collected; some specimens of which are preserved in the Hunterian Museum

in icebergs, several hundred feet above the level of the sea; and so well preserved, that in one instance eight or ten barrels of oil were obtained from a portion of the body that had fallen out of an ice-cliff from an elevation of 280 feet.—Lyell's Second Visit to the United States, vol. i. p. 37.

* A detailed account of this animal and its discovery was communicated by Dr. Tilesius in the Memoirs of the Imper. Acad. of Sciences at St. Petersburg (vol. v.); and a Translation of this Memoir was published in 1819, 4to, London), accompanied by a lithograph, of which *Lign.* 24 is a reduced sketch. The skin still remains attached to the head and feet of the specimen.

at the College of Surgeons. The ears remained dry and shrivelled; the brain and even the capsule of the eye were



LIGN. 24.—SKELETON OF THE MAMMOTH, OR ELEPHAS PRIMIGENIUS, WHICH WAS FOUND IMBEDDED IN FROZEN GRAVEL IN SIBERIA.

(Twelve feet high, and sixteen feet long.

preserved! The bones and part of the integuments, and a considerable quantity of the hair, are in the Museum of Natural History at St. Petersburg The accompanying sketch (*Lign.* 24) represents the specimen in its present state.

The tusks are curved forward and upward. The teeth differ from those of the two living species of elephants, in the disposition of the plates of dentine (see p. 142), and also in their internal microscopic structure; the configuration of the skull is likewise peculiar; and these discrepancies, together with the hairy and woolly skin, led Cuvier to consider the species as having been adapted to exist in a colder climate than the living types inhabit. But that eminent philosopher also assumed, from the preservation of the bodies of these animals in ice, and the present low temperature and sterile condition of that part of Siberia where these remains abound, that a sudden change of climate had taken

place and continued, by which means the race was destroyed, and their remains entombed in the frozen soil.

Playfair, with that profound sagacity which characterized all his speculations on geological phenomena, first suggested the idea, "that the power of living in a different climate, and of enduring greater degrees of heat or of cold, and of subsisting on a different kind of food," may have belonged to the extinct elephants found in Siberia; "for, though one species," he remarks, "may now be confined to the southern parts of Asia, another may have been able to endure the severe climates of the north: and the same may be true of the rhinoceros, buffalo, &c. These animals may have lived farther to the south than where their remains are actually found, among the valleys between the great ranges of mountains that bound Siberia on that side. We must observe, too, that they may have migrated with the seasons, and by that means avoided the rigorous winters of the high latitudes."* And more recently, Sir C. Lyell, extending these views, suggested that a large region of central Asia, perhaps the southern half of Siberia, might, during the mammoth-period, have possessed a climate mild enough to support a vegetation fit for the sustenance of the fossil species; and, reasoning upon the present physical geography of the country, he thought that the whole tract from the Ural Mountains to the sea had been upraised, like Sweden (p. 116), and that the refrigeration of the north-east of Asia, and its present condition, were the result. These opinions have been confirmed by the recent investigations of Sir R. Murchison, which are so important, both in a geological and palæontological point of view, that I must offer a concise sketch of the facts and observations which bear upon this question.

* Playfair's Illustrations of the Huttonian Theory, Edinburgh edition of 1822, vol. i. p. 465. Dr. Fleming also supported these views.

20. MAMMOTHS OF THE ALLUVIAL DEPOSITS OF RUSSIA. —Premising, that with the remains of the mammoth and rhinoceros there occasionally occur bones of a gigantic beaver (*Trogontherium*), bear, great deer, ox, and a remarkable extinct pachyderm (*Elasmotherium*), we will first describe the nature of the deposits in which these relics are imbedded.

There is a great analogy in the geological character of the detritus composing the alluvial mammaliferous beds of Russia and those of our own island; both have evidently been formed under similar circumstances in river-deltas and estuaries, and off sea-shores, in water of moderate depth; they are in fact drifted materials, that were brought down by currents and streams from the dry lands inhabited by the animals whose remains they contain: and by the subsequent elevation of the coasts these littoral deposits have been raised to their present level.

In Siberia, the mammoth's remains are found in alluvial detritus in the flat northern tracts, or near the mouths of the great rivers. Even in all the central and southern parts of European Russia, from there being no high ridges of elevation, and consequently no coarse local detritus as on the flanks of the Ural Mountains, the mammoth-alluvium assumes the same aspect as in the distant plains of Siberia, where it is equally removed from disturbing causes.

A section exposed in an abrupt cliff on the Sea of Azof, at Taganrog, will explain the usual character of the deposits:*—

1. Clay-drift, containing numerous bones and teeth of the mammoth: 50 feet.
2. Band of finely laminated sands, full of shells probably of the same species as those that inhabit the adjacent river Don.
3. Tertiary newer miocene limestone: forming the base of the cliff: to the height of 20 feet.

From the nature of this drift, and its distribution at

* Geology of Russia and the Ural, vol. i. p. 502.

various levels, Sir R. Murchison infers that the greater part of this low continent, unlike the Ural and higher portions of Siberia, was not dry land during the existence of the mammoths, nor in the period immediately antecedent to our own; but was in the same subaqueous condition as the low lands of Northern Siberia, when the bones were transported into the then existing estuaries and bays.

21. SIBERIA AND RUSSIA IN THE MAMMOTH-EPOCH.—These observations of Sir R. Murchison clearly prove, that the mammoths cannot have inhabited the northernmost flat tracts of Siberia in which their remains are imbedded, for the wide and low districts of that sterile region were beneath the sea at the period when these extinct animals existed; the bones and carcasses must, therefore, have drifted thither, and probably from a considerable distance. The mammalian remains do not occur on the elevated chains of hills; and, from the physical structure of the country, it is probable that not only the Ural and Altai Mountains, but also their northern ridges and terraces, which include more than half of Siberia, were covered with forests in some parts, and with brushwood-steppes in others; and herds of mammoths may have migrated thence in the summer season (which is even now intensely hot) to the embouchures of the great streams and the borders of the then Arctic Sea. From a masterly review of the phenomena relating to this subject, by Sir R. I. Murchison, we gather that—*

A former terrestrial surface, on which the great quadrupeds lived for ages, and the rupture and diminution of adjacent lakes, coincident with some of the last elevations of the Ural chain, will best explain the condition in which the remains of mammoths are found buried on the edges of the uplifted ridges of the Ural, as well as in the low lands and great estuaries farthest removed from them.

As we advance into the plains of Siberia, or descend into the valleys of the Tobol and the Obe, the bones are in greater quantities and in a better

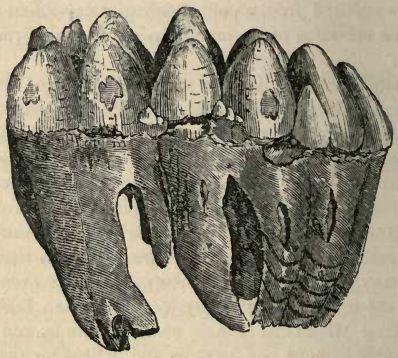
* Geology of Russia and the Ural, vol. i. chap. xix.

state of preservation; and the farther the Siberian rivers are followed to their mouths, the more do the mammalian remains increase, until at length whole skeletons, and even carcasses, are found. The single fact of the very wide diffusion of mammoth-bones over enormous regions, in itself indicates that those creatures had long been inhabitants of such countries, living and dying there for ages; whilst their final destruction may have resulted from aqueous debacles dependent on oscillations of the land, the elevation of mountain-chains, and the formation of much local detritus.

The Siberian mammoth, having a close coating of wool and much shaggy hair, seems to have been adapted to inhabit the regions of northern Europe and Asia; and the elevation of large tracts of land in Siberia, by laying dry the low shores and estuaries into which their bones had been washed, would necessarily render the climate more intensely cold. The intimate structure of the teeth in the mammoth differs from that of the Asiatic and African elephant, and is supposed by Professor Owen to indicate that the extinct creature lived on coarser ligneous tissue of trees and shrubs, that may have constituted forests, extending even into the promontories of the icy sea, ere the physical events had taken place which elevated the Ural Mountains to their present altitude, and left the coasts with no vegetable support but the moss and lichens for the rein-deer and musk-ox (buffalo), with which the mammoths were once contemporary.

22. THE MASTODON.—In various parts of North America there are marshy tracts abounding in salt and brackish waters, that are frequented by deer and other animals; a circumstance from which these swamps have acquired the American name of *Lick*. In these morasses vast quantities of bones and several entire skeletons of elephants and other gigantic quadrupeds have been discovered. The spot most celebrated for these remains in Kentucky is called Big-bone Lick, which is situated to the south-east of the Ohio, in the midst of a group of low hills, and is traversed by a small stream of brackish water. The bottom consists of black fetid mud, intermingled with sand and vegetable matter; and in this bog bones occur in abundance. Some of them are referable to the mammoth; but others, as you may observe from the specimens before us, belonged to a creature

not less gigantic, but with very distinct characters. These teeth are composed of dentine and enamel; and the latter is spread over the crown of the tooth, which, before it is



LIGN. 25.—TOOTH OF THE GREAT MASTODON, FROM THE BANKS OF THE HUDSON; WEIGHT 4 lbs; ONE-THIRD NATURAL SIZE LINEAR.

(Mastodon Ohioticus.)

worn by use, is divided into several transverse tubercles, or processes, each of which is subdivided into two obtuse points, these transverse ridges not being filled up with cement, as in the elephant; from this form of the crown of the tooth the animal to which it belonged has received the name of MASTODON, signifying mammillary tooth.* These teeth have no relation whatever to those of the carnivora; for, though they have an external investment of enamel, as in the teeth of the tiger, they are destitute of the longitudinal, serrated, cutting edge; and in those which are worn, the protuberances become truncated into a lozenge form. This structure is fitted for the grinding and mastication of tough

* Pictorial Atlas, pl. 74.

and hard vegetable substances. The bones and teeth of the mastodon have been found throughout the plains of North America, from north of Lake Erie to as far south as Charleston in South Carolina. There were also mastodons peculiar to Central and Southern America. The remains of other species have been discovered in the Crag of England, in France, Switzerland, Germany, Spain, and Italy, in Asia Minor, and in several parts of India.*

These remains are met with under many varieties of condition; but those of Kentucky are found in marl, beneath peat-bogs, at moderate depths, and with no marks of attrition; it is therefore evident that the animals lived and died in the country where their relics are entombed.

In the suburbs of Rochester (U. S.) many bones of mastodons were dug up from a bed of clay which contained numerous river-shells of existing species (*planorbis, valvata, limnæa, cyclas*, &c.). The skeletons of the great mastodon found in the bogs of Louisiana were in a vertical position, as if they had sunk in the mire; and one discovered imbedded in black earth in New Jersey, forty miles to the south of New York, was in the same position, the head being on a level with the surface of the soil. There is now an entire skeleton of the mastodon in the British Museum.† From this specimen it appears that the great mastodon of the Ohio was not unlike the elephant in its general outline, though somewhat longer and thicker. It had a trunk or proboscis, tusks, which curved upward, and four molar teeth in each jaw; the tusks being the only "incisors."

But another remarkable peculiarity, and which entirely separates the mastodon from the elephant, is that the young animal had a pair of tusks, placed horizontally in the lower jaw; and of these tusks, one only became developed, and that

* See Cautley and Falconer's *Fauna Sivalensis*.

† Fossils of the British Museum, p. 472.

in the adult male; both were early shed in the female.* The tusks are composed of ivory, and vary somewhat in the direction and degree of their curvature.

In the midst of a collection of mastodon bones imbedded in mud, a mass of small branches, leaves, grass, and a common Virginian species of reed, in a half bruised state, was discovered; the whole appeared to have been enveloped in a sac, probably the stomach of the animal. In another instance, traces of the proboscis were observed. The bones of this colossal quadruped are found remarkably fresh and well preserved, and are generally impregnated with iron. No living instance of this creature is on record, and there can be no doubt that its race has long since been extinct. The Indians believe that men of equally gigantic proportions were coeval with the mastodon, and that the Great Spirit destroyed both with his thunder.†

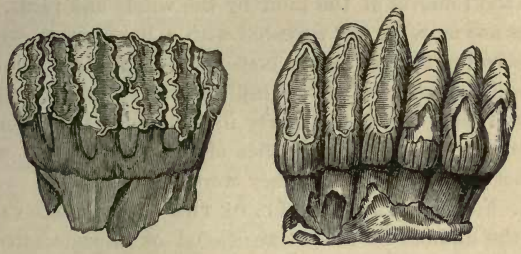
The North American mastodon is known as the *M. Ohioticus*, and appears to have been limited to that country. Humboldt discovered a tooth of a mastodon near the volcano of Imbaburra, at an elevation of 1200 fathoms. In England, a few mastodon teeth have been found in the Norwich Crag; these belong to a species named *Mastodon angustidens* (*narrow-toothed*).‡

23. MASTODONS FROM AVA.—I have now to call your attention to the fossil remains of several species of mastodons which, from the structure of the teeth, fill up, as it were, the interval that separates the mastodon from the elephant: one of these was in consequence named by Mr. Clift *Mastodon elephantoides* (*Lign.* 26, *fig.* 2). These teeth present very peculiar characters; for, while in their general appearance they resemble those of the mastodons already

* Professor Owen. † Cuvier. Oss. Foss.

‡ The British Museum now contains an unrivalled collection of the fossil remains of mastodons and mammoths from North and South America, and India.

described, the crown of the tooth is deeply ridged, and the dentine and enamel are invested with so large a portion of



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LIGN. 26.—FOSSIL TEETH OF THE ELEPHANT AND MASTODON.

(One-sixth the diameter of the originals.)

Fig. 1. Tooth of the *Elephas primigenius*, from Big-bone Lick.
2. Tooth of the *Mastodon elephantoides*, from near Ava.

cement, as to give the worn surface of the crown the aspect of the molars of the true elephant.

The specimens before us, consisting of teeth and bones of mastodons, elephants, hippopotami, rhinoceroses, horses, tapirs, antelopes, gavials, fresh-water turtles, &c., and silicified wood, are part of an extensive collection formed about twenty years since by Mr. Craufurd, on his mission to Ava. In descending the river Irawaddi, his steam-boat, owing to the shallowness of the water, ran aground between Prome and Ava, about 20° north latitude, near some petroleum-wells, where the bank of the river presented a cliff 80 feet high; and on the strand were observed masses of petrified wood and vast quantities of bones. The adjacent country is formed of low sterile sand-hills, intersected by ravines, with beds of gravel, which are here and there cemented into a conglomerate by iron and carbonate of lime.

Scattered over the surface, in some instances lying loose in the sand, and in others half buried, were masses of silicified wood, and fragments of bones, which had become exposed, from the removal of the sand by the winds and rains. The bones are more or less invested with a hard crust, which is a concretion formed by the consolidation of loose sand from ferruginous and calcareous infiltrations. The natives, who assisted Mr. Craufurd's party in collecting these remains, believed them to be the bones of giants that had warred against Vishnu, by whom they were destroyed.

24. FOSSIL MAMMALIA, &C. OF THE SUB-HIMALAYAHS.—But the number of these transitional or intermediate links of elephantine forms has been greatly increased by the accession made to our knowledge of the fossil fauna of India, by the labours of Col. Sir Proby Cautley and Dr. Falconer, who, with energy and perseverance beyond all praise, formed and brought to Europe an immense collection of these mammalian remains. The following extract from the prospectus of a work now in the course of publication by these eminent naturalists will convey some idea of the richness and interest of their discoveries:—

"The fossil Fauna of the Sewalik range of hills, skirting the southern base of the Himalayahs, has proved more abundant in genera and species than that of any other region yet explored. As a general expression of the leading features, it may be stated, that it appears to have been composed of representative forms of all ages, from the oldest of the tertiary period down to the modern, and of all the geographical divisions of the Old Continent, grouped together into one comprehensive Fauna in India. Of the forms contained in it may be enumerated, in the *Pachydermata*, several species of Mastodon and Elephant, the hexaprotodon Hippopotami, Merycopotamus, Rhinoceros, Anoplotherium, Sus, and three species of Equus; in the *Ruminantia*, the colossal genus Sivatherium, peculiar to India, with species of Camelus, Camelopardalis, Bos, Cervus, and Antelope; in the *Carnivora*, species of most of the great types, together with several remarkable undescribed genera; in the *Rodentia*, several species; in the *Quadrumana*, several species; in the *Reptilia*, a Gigantic Tortoise (*Colossochelys*), with species of Emys and Trionyx, and several forms of

Crocodile. To these may be added the fossil remains of Birds, Fishes, Crustacea, and Mollusca." *

25. Sub-Himalayan tertiary deposits.—The deposits from which these remains were obtained resemble those of Ava already mentioned, and consist of concretionary grit, conglomerate, sandstone, and loam; they are spread over the flanks of a range of hills belonging to the Sub-Himalayan mountains, between the river Sutlej and the Ganges. These hills, which Col. Cautley terms the Sevâlik Range, rise to an altitude of from one to three thousand feet above the level of the sea. The Sevâlik or Sub-Himalayan deposits extend about 200 miles in length, and seven in width, and dip to the nor that an average angle of 25°; wherever gullies or fissures expose sections of the beds, abundance of fossil bones appear.† Lignite and trunks of dicotyledonus trees occur; a few land and freshwater shells of existing species are the only vestiges of mollusca that have been observed. Remains of several species of river-fish, some related to the recent Silurus, have been obtained.

The immense collection of these fossils in the British Museum‡ renders any detailed description unnecessary, and I will only dwell on a few of the most important particulars.

The remains of the elephants and mastodontoid animals comprise perfect specimens of skulls and jaws, of gigantic size. The tusks of one example are 9 feet 6 inches long, and 27 inches in circumference at the base.§

* "*Fauna Antiqua Sivalensis*, being the Fossil Zoology of the Sewalik Hills, in the north of India," by Hugh Falconer, M. D., and Captain (now Col. Sir) Proby T. Cautley, *fol.* Nine Nos. (1845-49) have been published.

† See an interesting Memoir by Sir P. Cautley; Geol. Trans. 2nd Series, vol. v. p. 267.

‡ See Fossils of the British Museum, p. 468.

§ These fossils are so admirably cleared from the hard rock with which they were incrusted (a task of no little labour, and requiring great skill), that I cannot forbear recommending to the notice of any collectors who

26. REMARKABLE COLLOCATION OF FOSSIL ANIMALS.—But this collection is invested with the highest interest, not solely on account of the number and variety of the specimens, but also for the extraordinary assemblage of animals which it presents. In the Sub-Himalayas we have entombed in the same rocky sepulchre bones of the most ancient extinct races of mammalia, with species and genera which still inhabit India! Palæotheria, Anoplotheria, Dinotheria, Mastodons, Elephants, Giraffes, Hippopotami, Rhinoceroses, Horses, Camels, Antelopes, and even Monkeys; Struthious birds, and Crocodilian and Chelonian reptiles. To this concise enumeration must be added several genera previously unknown; large rodents, and insectivora, &c.

Among these marvellous relics of the past, are the skull and bones of an animal named *Sivatherium* (from the Indian deity *Siva*), that requires a passing notice. This creature forms, as it were, a link between the ruminants and the large pachyderms. It was larger than a rhinoceros, had four horns, and was furnished with a proboscis; thus combining the horns of a ruminant with the characters of a pachyderm. When living it must have resembled an immense antelope or gnu, with a short and thick head, and an elevated cranium crested with two pairs of horns; the front pair were small, and the hinder large, and set quite behind, as in the aurochs; with the face and figure of the rhinoceros, it had small lateral eyes, great lips, and a nasal proboscis.

Among the reptilian remains are skulls and bones of a Gangetic Crocodile or Gavial, and of a land Turtle, which cannot be distinguished from those of species still living in India. But the most extraordinary discovery is that of bones and portions of the carapace of a Tortoise of gigantic dimensions; it has been aptly named *Colossochelys Atlas:* the length of this reptile exceeded *twelve feet.*

may require such aid the person by whom they were chiselled out—*James Dew*, 25, *Harrison Street, Gray's Inn Road.*

27. The Pampas.—The Pampas, those vast plains in South America which present a sea of waving grass for 900 miles, are principally composed of alluvial loam and sand containing freshwater and marine shells, and were once, like Lewes Levels, a gulf or arm of the sea. In these alluvial deposits, bones of enormous extinct mammalia have frequently been discovered. Towards the close of the last century, an almost perfect skeleton of a gigantic animal (*Megatherium*) was dug up, at a considerable depth, in a bed of clay, on the banks of the river Luxor, about four leagues W. S.W. of Buenos Ayres. This skeleton was sent, in 1789, to the museum at Madrid, where it now remains. It is described and figured by Cuvier, under the name of *Megatherium.*

In 1832, Sir Woodbine Parish, with considerable labour and expense, collected many bones of a similar creature from the Salado; having actually diverted for a time the river from its course, that he might disinter these remains; these he afterwards presented to the Hunterian Museum at the Royal College of Surgeons.

Since that time relics of several other remarkable forms of extinct mammalia have been discovered; a few of these we will here briefly describe.

The Pampas, observes Mr. Darwin, may be regarded as one vast sepulchre of these lost quadrupeds. The deposits in which the bones occur are as follow:—

1. Red clayey earth with calcareous concretions and bones of terrestrial animals.

2. Indurated marl.

3. Clay, sand, and limestone, containing marine shells and shark's teeth, and forming the substratum.

This section demonstrates that a bay of salt water was gradually encroached upon, and at length became the bed of a muddy estuary, into which floated the carcasses of the animals which then inhabited the neighbouring dry land. It is in the upper deposits that the teeth and bones of the Me-

gatherium, Mylodon, and other gigantic animals of the Sloth tribe, Armadillo, Mastodon, Horse, &c., are imbedded.*

28. THE SLOTH TRIBE. — The most remarkable of the fossil bones discovered in the Pampas belong to several extinct colossal animals of the *Edentata ;* † an order of which the Armadillos, Sloths, and Ant-eaters are the living representatives. But as the extinct forms differ greatly from the existing ones, in their gigantic proportions, short massy extremities, and thick and strong tail, their mode of life must have been very dissimilar. To impart a clear perception of the peculiar modification of structure which these extinct beings present, it will be necessary to offer some remarks on the existing types—the Sloths.

The Sloths are arranged by naturalists in a tribe termed *tardigrada*, from their feeble power of progression on the surface of the land; for the same reason they are called *Paresseux* by the French, and *Sloths* by the English. They are of slender form and small size: the largest species is but little larger than a cat. They have long toes, and nails which fold up, so as to enable the animal to walk in the same way as if our fingers were folded under the palms of the hands, but which are not capable of being retracted into a sheath, as in the feline tribes. The arms are double the length of the legs, and, from the construction of the limbs, the animal, when it walks, or rather crawls on the ground, is obliged to drag itself along on its elbows. But these creatures are destined to inhabit trees; their proper element is on the branches, and they can pass from bough to bough, and from tree to tree, with a rapidity which soon enables them to lose themselves in the depths of the forests. They live on the leaves and the young shoots, and, unless disturbed, never quit a tree until they have stripped off every leaf. To avoid the labour of a descent, they drop to

* Mr. Darwin; Appendix to Beechey's Voyage.

† So named from some of these animals having no teeth.

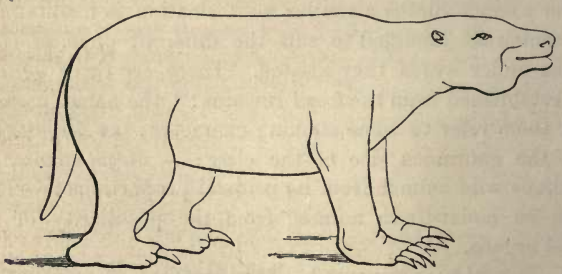
the ground, previously coiling themselves into a round ball, in which state, while attached to the branch, they may be taken alive. Thus the habits and economy of the sloth point out the necessity for a peculiarity in the structure of its claws. The monkey leaps and swings himself from tree to tree, and catches at will the branches or the trunk; but the sloths do not grasp; their claws are mere hooks to hang by, and their great strength is in their arms. They never unfix one set of hooks until they have caught a secure hold with the other, thus hanging by their arms and legs, while their bodies are pendant; and they sleep in the same position. The bones of the arm are constructed to suit these conditions. The humerus has a long internal condyle for the origin of large muscles to move the enormous claws, and there is an opening for the passage of the principal nerves and blood-vessels, to protect them from the pressure to which they would be exposed from the powerful muscular action: and the radius (one of the bones of the fore-arm) is constructed to allow of a free rotatory motion to the limb. In the extinct Sloths a similar conformation is maintained, but somewhat modified to suit the different physical conditions under which they existed. There are three genera well established from the fossil remains: * the names assigned to them refer to some striking character; as *Megalonyx*, from the enormous size of the claw: — *Megatherium*, or enormous wild animal, from its colossal proportions: — *Mylodon*, or molar-tooth animal, from the peculiarity of its dental organs.

29. The Megatherium.†—This creature was seven feet high, and nine long, and therefore larger than the largest rhinoceros; but this comparison by no means conveys a proper idea of its bulk, since its proportions are perfectly colossal, the thigh-bone being three times as large as that of

* See Medals, vol. ii. p. 798.

† Owen; Phil. Trans. Fossils of the Brit. Mus p. 477, *lign.* 112, 113

the elephant, and the pelvis, or haunch-bone, twice the breadth. It possesses no incisor teeth, and the grinders, which are seven inches long, are of a prismatic form, and, like those of the Sloth, composed of dentine and cement.* They are so formed, that the crown always presents two cutting, wedge-shaped, salient angles. As in an adze, a plate of steel is placed between two of iron, so as to project in a line, in like manner these teeth have in the centre a cylinder of ivory, which is protected by a plate of denser structure, and an external coating of cement; they are, therefore, admirably adapted for cutting and bruising vegetable substances. The entire fore-foot is about a yard in length, and armed with strong claws. The pelvis measures five feet in width, and the sacral aperture of the spinal marrow is one foot in circumference! This enormous size was suitable to the habits of an animal requiring to maintain an



LGN. 27.—RESTORED OUTLINE OF THE MEGATHERIUM AMERICANUM. *Blumenbach.*
The original 12 feet in length.

upright posture for a considerable time, while employing its fore feet in digging up roots, or in severing and pulling

* Prof. Owen's "Odontography," vol. i. p. 338; and Phil. Trans. vol. cxlvi. p. 579.

down the young trees and branches, which doubtless constituted the food of this colossal creature.

The *Megatherium* was intermediate between the Sloths, Armadillos, and Ant-eaters; for, while in its skull and shoulders it resembled the former, its legs and feet presented an admixture of the characters of the latter.

30. THE MYLODON.—This creature was nearly as large as the Hippopotamus, but shorter. Its hinder extremities are relatively short, and the feet are placed at right angles with the legs, and are as long as the thigh bones. The tail is remarkably thick and strong, and as long as the hinder extremities. The pelvis is very massive and solid. The ribs are as stout and broad as in the elephant. The fore-legs, or arms, are connected to the sternum by powerful clavicles, and are so constructed as to admit of unrestrained motion in every direction. The toes are five in number on each fore foot, and four on the hinder; the two external toes are unarmed, the others have powerful curved nails or claws. This creature had claws and hoofs on the same foot, and therefore connects the two great groups of recent animals, the *ungulata* and *unguiculata*.

The skull is long, narrow, and smaller than that of the ox; it terminates in a flat or truncated muzzle. The bones of the upper part of the cranium are of enormous thickness, large air-cells being interposed between the inner and outer table. The teeth, which are implanted in very deep sockets, are of the same form and size throughout, and closely resemble in structure those of the Megatherium, but the surface of the crown when worn is flat; there are four on each side in the lower, and five in the upper jaw.

There is a magnificent skeleton of this creature in the Hunterian Museum; it is as perfect as if the animal had recently been buried, and the bones dug up entire. It is eleven feet long, from the muzzle to the extremity of the tail.*

* See a Memoir on the "Skeleton of an extinct gigantic Sloth (*Mylodon robustus*)," by Professor Owen. 4to, with plates, 1842.

The Mylodon, like the Megatherium, was a vegetable feeder, and probably browsed on the shrubs and branches of trees. The arms are especially adapted for grasping and wrenching; and, though no trees could support the weight of this enormous creature, there is nothing to forbid the supposition that with its hinder feet it could clasp the trunk of a large tree, and with its fore feet climb to a sufficient height to seize and wrench off the branches.

31. THE MEGALONYX. — An enormous curved ungueal phalanx or claw-bone and several bones of the arm and sternum of an animal related to the Sloths were found many years since in Big-bone Cave, one of the numerous saltpetre caverns which occur in the States of Kentucky, Tennessee, and Virginia. Some of these caves extend many miles under ground, passing beneath hills, valleys, and even rivers. In these subterranean retreats are sometimes found Indian mummies, which are simply desiccated human bodies, in a fine state of preservation; bones of existing species of mammalia, and of mastodons, mammoths, and, rarely, of extinct gigantic sloths, also occur.*

The remains of the Megalonyx were first described by President Jefferson; and the claw-bones, the largest of which was nearly seven inches long, excited especial attention, from the supposition that they belonged to a carnivorous animal of marvellous size. But Cuvier, in an admirable memoir, proved that they were referable to an extinct form of the Edentata. I will endeavour briefly to explain how this beautiful induction was established.

The paws both of the canine and feline tribes are armed with claws: in the former the nails are thick and coarse, as in the dog, wolf, &c., and will bear the friction and pressure incident to a long chase; but in

* See Dr. Harlan's Medical and Physical Researches, 8vo, 1845, p. 319; also American Journal of Science, for May, 1851.

the cat tribe, they are curved and sharp, and these qualities are preserved by a particular mechanism. The last bone which supports the claw is placed laterally to the penultimate bone of the phalanx, and is so joined to it, that an elastic ligament draws it back, and raises the sharp extremity of the claw upwards; and the proximal or nearest extremity of the farthest bone presses the ground in the ordinary running of the animal, while the claw is retracted into a sheath; but, when the creature makes a spring and strikes, the claws are uncased by the action of the flexors or bending tendons. In the Bengal tiger, the claws are so strong, and the arms so powerful, that they have been known to fracture the skull of a man, by a single touch from the animal in the act of leaping over him. A cat affords a familiar illustration of this peculiarity of structure; when pleased, its claws are retracted, and when angry they are thrown out.

In the claw of the Megalonyx there is no such lateral provision for its retraction, and the point could not have been raised vertically, as in the cat, so as to have permitted the foot to touch the ground without injury to the point of the claw. The articulating surface is double, that is, there is a ridge or spine in the middle, and it must, therefore, have moved like a hinge. The bones of the arm present a corresponding configuration with those of the sloth; the humerus is perforated for the passage of the blood-vessels, and the radius is constructed for rotation.

The Megalonyx probably resembled the Megatherium in its general character, configuration, and habits, but was one-third smaller than that gigantic creature.*

32. THE GLYPTODON—so named from the deeply-grooved teeth—was an animal allied to the Armadillos, and possessed a carapace, or coat of mail, formed of polygonal bony plates united by suture, which constituted an impenetrable covering over the upper part of the body. The plates of this bony integument were not disposed in rings as in the armadillo, but were articulated to each other, and formed a tesselated cylinder, or rather arch; the tail was enclosed in a case of this kind, like a sword in its scabbard.†

* Casts of all the bones and teeth of the Megalonyx that are in the Museum of Philadelphia were presented to Dr. Mantell by Dr. S. G. Morton of that city, and are now in the British Museum.

† Fossils of the British Museum, p. 359; Medals, vol. ii. p. 799. A

Such were the gigantic Edentata that inhabited the dry land of South America at a comparatively modern period; and it is worthy of especial remark, that, though these beings have long been extinct, sloths, ant-eaters, and armadillos, but of diminutive size, are still the characteristic mammalia of that country.

33. THE TOXODON.—The bones of several other extinct quadrupeds have been found with the relics of the gigantic sloths and armadillos. Among these are the skull and teeth of an animal of large size, named by Professor Owen *Toxodon*, from the singularly curved form of its molar teeth. The skull is twenty-eight inches long and sixteen broad, and presents a blending of the osteological characters of the several existing natural orders of the rodentia, ruminantia, and cetacea.

The MACRAUCHENIA, another extinct pachyderm, found in Patagonia, unites in a remarkable degree the structure of the Camel and Tapir; it must have somewhat resembled the Llama, but had a neck surpassing in length that of any other animal, except the Giraffe.*

34. FOSSIL HIPPOPOTAMUS, RHINOCEROS, HORSE, &C.—With the remains of the mammoth, elephant, and other large mammalia, teeth and bones of several species of hippopotamus, horse, deer, ox, and aurochs are very commonly associated in the alluvial deposits of Europe. In the Vale of Arno, in Italy, immense quantities of the teeth and bones of hippopotami are found; on the table before us are specimens from that locality; as well as molars and incisors of a young animal from Huntingdonshire; and tusks, teeth, and

splendid specimen of the bony cuirass of the Glyptodon is in the Museum of the College of Surgeons.

* An account of the extinct animals of South America, by Professor Owen, will be found in Mr. Darwin's "Zoology of the Voyage of the Beagle."

bones, dug up in alluvial marl, at Southbourn, in Sussex. Several extinct species have been determined by Cuvier, one of which was not more than half the size of the common hippopotamus.

The bones and teeth of the Rhinoceros are frequently associated with those of the fossil elephant; and they occur in the gravel and loam of the Thames valley, and in many other parts of Britain. I have obtained specimens from a bed of gravel, on Petteridge Common, in Surrey, and from loam at the *Wish*, near Southbourn, in Sussex.

The most extraordinary and interesting fact, relating to the rhinoceros in a fossil state, is the discovery of the entire carcass, covered with its skin, in frozen sand, on the banks of the Wilaji, in Siberia, as previously mentioned (p. 152). The head was extremely large, and sustained two very long horns; it had no incisors; the body and limbs were covered with brown hair; the general form of the animal was lower and more compact than the living species.

The teeth and bones of one or more species of Horse occur very constantly with those of the other large extinct pachyderms. In these examples of the conglomerated shingle from Brighton cliffs (see p. 113), the coffin, pastern, and cannon bones, as they are termed, of a small species, about the size of a Shetland pony, are imbedded; in some instances the cavities of the long bones are filled with crystallized carbonate of lime.

In addition to those already mentioned, the deposits now under examination contain vestiges of other lost forms of mammalia. The fossil remains of an animal resembling the Musk-ox * were found with elephants' bones in Siberia; of an extinct species of Fallow-deer in Scania; of Roe-buck

* The Musk-ox, or rather Musk-buffalo (*Owen*), has been of late discovered fossil both in Berkshire and near Bath; see Quart. Journ. Geological Society, vol. xii. p. 124; and British Assoc. Reports, 1856.

and Rein-deer * in France and England; and of gigantic Oxen, Aurochs,† Deer, &c., in our own country. It is worthy of remark, that the fossil pachyderms, such as the elephant, rhinoceros, &c., belong to genera which are now restricted to torrid climes, while the ruminants resemble those which at the present time are natives of northern latitudes.

35. THE DINOTHERIUM.‡—I shall conclude this notice of the fossil mammalia, with an account of a gigantic creature whose bones occur with those of the mastodon, elephant, and other terrestrial quadrupeds, previously described.

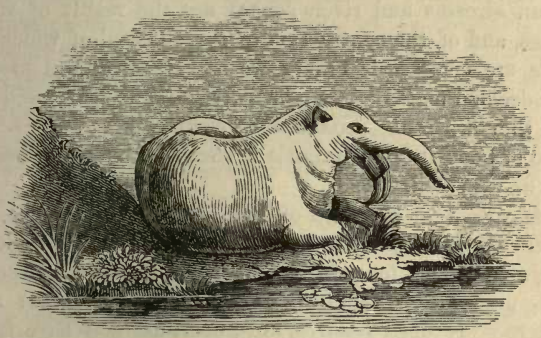
In various parts of the south of France large molar teeth, resembling in form and structure those of tapirs, have occasionally been found; they are described by Cuvier under the name of the "*Gigantic Tapir.*" Subsequent discoveries in Bavaria, Austria, and particularly at Eppelsheim, about twelve leagues south of Mayence, have thrown light on the osteology of the original, which appears to have been an aquatic or amphibious animal of great size. The most extraordinary deviation from ordinary types consists in a pair of curved tusks, which are fixed in the lower jaw, and directed downwards. From the structure of the anterior portion of the cranium, and the disposition of the nasal fossæ, it is supposed that the creature had a proboscis; it possessed no incisor teeth with which to seize its food, and the jaws could not even close together in front; the lower jaw is four feet in length. The tusks resemble those of the Walrus, and

* For the discovery of the skull of a Rein-deer in the alluvial loam filling up fissures in the tertiary limestone at Binstead, Isle of Wight, see Geology of the Isle of Wight, p. 73.

† The Aurochs is a species of wild bull or buffalo, distinct from the common ox. The horns of the fossil ox are sometimes of enormous size: Mr. Parkinson had a pair in which the length of each horn was 2 feet 7 inches. See also Owen's Foss. Brit. Mammals; and Foss. Brit. Museum, p. 390.

‡ *Deinos*, terrible; *therion*, a wild beast. Foss. Brit. Mus. p. 474.

were probably weapons of defence.—This drawing (*Lign.* 28), from a restoration by M. Kaup, an eminent German



LIGN. 28.—RESTORED FIGURE OF THE DINOTHERIUM.

naturalist, to whose researches we are mainly indebted for the important discoveries at Eppelsheim, represents the supposed form of the original creature. It has been assumed that the Dinotherium was nearly related to the hippopotamus, and formed a link between the cetacea and pachyderms; but it seems more probable that it was an herbivorous cetacean related to the Lamantins.

36. FOSSIL CARNIVORA IN CAVERNS.*—We have now briefly reviewed the extinct population of a remote period of our globe,—those enormous terrestrial mammalia, the mastodons, mammoths, &c., that lie buried in the alluvial and superficial strata. We pass to the consideration of a phenomenon not less interesting—the occurrence of immense quantities of bones of many species of carnivora in fissures and caverns. In the former discourse I alluded to the chasms which occur in certain limestone rocks, and described the process by which their roofs, floors, and walls

* See Petrifactions and their Teachings, p. 394.

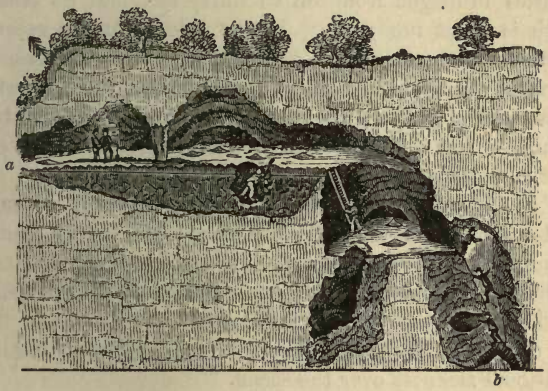
become lined with stalactites and stalagmites (p. 77). Some of these hollows have evidently originated in the destruction of the softer portions of the rock by the erosion of subterranean streams and rivers; many are the result of subsidences, and of the contraction of the material of which the strata are composed; others are so extensive, and present such decided marks of angular fracture, as to leave no doubt that they are rents produced by earthquakes. The occurrence of bones of land-animals in such chasms might reasonably be expected.

The caves that admitted of easy access from without, and which contain large quantities of bones of but a few species of carnivora, may for a while have been tenanted by species whose habits lead them to retire into secret recesses; and, if there were open fissures, kids, deer, &c. may have fallen in, and their bones have become enveloped in calcareous incrustations. But the bones and teeth of herbivora and carnivora that are promiscuously intermingled in loam and clay at the bottom of fissures and caves have evidently been drifted in, while the land was under water.

37. CAVE OF GAYLENREUTH.—For many centuries, certain caverns in Germany have been celebrated for their osseous treasures, particularly those in Franconia:* the most remarkable is that of Gaylenreuth, which lies to the northwest of the village, on the left bank of the river Wiesent. The entrance (*Lign.* 29, *a*), which is about seven feet high, is in the face of a perpendicular rock, and leads to a series of chambers from fifteen to twenty feet high, and several hundred feet in extent, terminating in a deep chasm (*b*), which, however, has not escaped the ravages of visitors. This cavern is perfectly dark, and the icicles and pillars of stalactite, reflected by the torches which it is necessary to

* See Medals of Creation, vol. ii. p. 820, for an interesting account of the Sophienhöhle, by Major Willoughby Montagu.

use, present a highly picturesque effect. The floor is literally paved with bones and fossil teeth; and the pillars and corbels of stalactite also contain osseous remains. A description of this cave was published by M. Esper, in the middle of the last century; at that period, the innermost recesses contained waggon-loads of bones and teeth; some imbedded in the rock, and others in the loose earth. The bones are in general scattered and broken, but not rolled; they are lighter and less solid than recent bones, and are often incrusted with stalactite.



LIGN. 29.—VERTICAL SECTION OF THE CAVE OF GAYLENREUTH.
a, The entrance of the cave; *b*, one of the deep recesses

Cuvier, who examined a very large collection of bones from Gaylenreuth, determined that at least three-fourths of the osseous contents of the caverns belonged to bears; and the remaining portion to hyenas, tigers, wolves, foxes, gluttons, weasels, and other small carnivora. Most of the bones which are referable to bears belong to two extinct species.

The largest has the skull more prominent in front than any living species, and is called *Ursus spelæus*,* or bear of the caverns; the other has a flat forehead, and is named *Ursus priscus*. The hyena was allied to the spotted hyena of the Cape, but differed in the form of its teeth and head. Bones of the elephant and rhinoceros are also said to have been discovered, together with those of existing animals, and fragments of sepulchral urns of high antiquity.†

38. FÖRSTERSHÖHLE (*Forest Cavern*). — This cavern, which is situated in the same part of Germany, is remarkable for the beauty of its stalactites and sparry incrustations; it varies in height from ten to thirty feet, and its greatest width is about ten yards. In the side vaults or recesses, which descend, at an angle of about forty-five degrees, into the main chamber, the stalagmite has formed the appearance of cascades of pure alabaster, the waves of which seem to be rushing out at the bottom, to pour themselves into the stagnant lake of the same substance which cover the floor. The roof has been corroded into deep cavities, which are separated by partitions of every conceivable form and tenuity, giving it the appearance of the richly fretted gothic roof of a chapel, with pendent corbels. Beautiful stalactites, depending from these projections, reach almost to the floor, and contribute by their delicacy and transparency to throw additional richness over the scene.

It is certainly, as M. Cuvier remarks, a most extraordinary fact, that caves spread over an extent of two hundred leagues should have the same osseous contents. The relative proportions of the different species are computed to be as follow:—three-fourths belong to bears, two-thirds of the remainder to hyenas, and a small number to the tiger or lion, and to the wolf or dog; rolled pebbles of a greyish-blue

* Pictorial Atlas, pl. 73.

† See Medals of Creation, vol. ii. p. 811, and Fossils Brit. Museum, p. 398, for further details relating to the fossil carnivora.

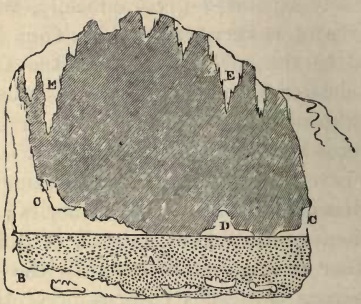
marble are the only extraneous materials found with the bones. The singular assemblage of species whose recent types are widely separated geographically, which some of these caves present, is very remarkable. Thus in one cavern, animals allied to the spotted hyena of the Cape of Good Hope are associated with the remains of others related to the glutton, which inhabits Lapland; and in another, bones of the rhinoceros with those of the reindeer.

Numerous caves containing osseous remains are scattered over the continents of Europe and America; and in Australia, fossil bones referable to animals of different genera are found under similar conditions. In the Brazils there are also numerous ossiferous caverns presenting the same general character. These bones belong, for the most part, to genera which still inhabit South America. It is worthy of especial notice, that the bones of a species of horse occur in these accumulations; for when the Spaniards invaded the country horses were unknown to the inhabitants, who, upon seeing a Spaniard on horseback, actually supposed that the man and horse were but one animal. At the present time, herds of wild horses, the descendants of those introduced by the Spaniards, are distributed over the vast plains of South America. "It is a marvellous event in the history of animals," observes Mr. Darwin, "that a native kind should have disappeared, and be succeeded in after-ages by countless herds introduced by the agency of man." *

39. Bone-caverns in England.—In England, caves and fissures containing bones of bears, wolves, and other carnivora, in every respect analogous to those of Germany above described, have been discovered and explored. Dr. Buck-

* Voyage of the Adventure and Beagle. A similar circumstance appears to have taken place in New Zealand: the fossil remains of a species of Dog have been found in some of the most ancient ossiferous deposits; but the present dog of the country, the Dingo, was introduced by the Maoris (according to their traditions) but a few centuries ago.

land, in his beautiful work, the *Reliquiæ Diluvianæ*, noticed several of the most important assemblages of this kind; of



4 feet.

LIGN. 30.—SECTION OF THE ENTRANCE TO KIRKDALE CAVE.

(*From Dr. Buckland's Reliq. Diluv.*)

A. Mud covering the floor of the cave to the depth of one foot, and concealing the bones.
B. Stalagmite containing bones, formed before the mud was introduced.
C. C. Stalagmite formed over the mud.
D. Insulated stalagmite on the surface of the mud.
E. E. Stalactites dependent from the roof.

these the cave of Kirkdale, in consequence of the highly interesting disquisition on its contents by Dr. Buckland, is the most celebrated.

In the summer of 1821, a deep fissure or chasm was discovered near Kirkdale, about twenty-five miles N.N.E. of York, in a bank about sixty feet above the level of a small valley, and near a public road. Some workmen, who were quarrying stone, cut across the narrow mouth of a chasm which had been choked up with rubbish, and overgrown with grass and bushes; and which, from this cause, as well as from its inaccessible situation, had hitherto escaped observation. The entrance was so small that a person could only enter in a bent position; and the passage was exceedingly irregular in its dimensions, varying from two to seven feet in breadth, and from two to fourteen feet in height, its greatest length being 245 feet. The cave was divided into several smaller cavities, which were nearly closed by sparry concretions; these occurred

where the roof was intersected by fissures, and continued for a few feet, but were gradually lost in the superincumbent limestone; they were thickly lined with stalactites. The true floor was only seen near the entrance, for in the interior the whole was covered with a bed of hardened mud or clay, about a foot in average thickness. The surface was perfectly smooth and level when the cave was first opened, except where stalagmites had formed upon it by infiltration from the roof. Where stalactitic matter incrusted the sides, it also extended over the bottom like a thin coat of ice, and therefore must have been deposited since the mud was introduced. This mud or clay was filled with fragments of bones belonging to a great variety of animals; and some of the bones exhibited marks of having been gnawed. From many corroborative circumstances these appearances were supposed, by the distinguished author, to have been occasioned by hyenas. The bones thus preyed upon belong to the tiger, bear, wolf, fox, weasel, elephant, rhinoceros, hippopotamus, horse, ox, and deer. Bones of a species of hare or rabbit, water-rat, and mouse, with fragments of the skeletons of ravens, pigeons, larks, and ducks, were imbedded with these remains.

From these facts Dr. Buckland inferred that the cave had been inhabited by hyenas for a considerable period, and that many of the remains found there were of species which

Lign. 31.—The right side of the lower jaw of a Hyena, from Kirkdale Cave.

had been carried in and devoured by those animals, and that in some instances the hyenas preyed upon each other; the gnawed portions of elephants' bones seem to show that occasionally the large mammalia also served as food. It is

probable that many of the smaller animals were drifted in by currents, or fell into the chasm, through fissures now closed up by stalactical incrustations.

KENT'S CAVE near Torquay in Devonshire, Oreston Cave near Plymouth, and Banwell Cave in the Mendip Hills, are well known for the abundance and variety of the fossil bones imbedded in alluvial drift, with which they are partly filled.*

Of these caverns, the first-named has been the most productive in objects of interest; probably from the diligent research carried on for many years by several local collectors. A very fine and extensive series obtained by the late Rev. J. MacEnery, of Torquay, is now in the British Museum. It comprises skulls and bones of all the species of carnivora usually met with in such recesses; and also the skull and teeth of the Badger, Otter, Pole-cat, Ermine, &c. Among these are a most remarkable canine tooth, six inches long, and an incisor, of a feline animal larger than the Tiger (*Machærodus latidens*); the edges of these teeth are serrated, and the canine is very like in form the tooth of the great Stonesfield reptile (the Megalosaurus). The teeth of another species occur in the caves of Germany; and a skull with teeth has been found in Auvergne. This extraordinary animal was originally named *Ursus cultridens* by Cuvier, who supposed it to have been an extinct species of Bear.†

But this cave is invested with additional interest on another account, which I will here briefly explain. The principal fissure extends 600 feet in length, and there are several lesser lateral ones. The lower part of the cave is filled up to a thickness of 20 feet with reddish sandy loam full of fossil bones. This is covered by a layer of stalagmite, from one to four feet thick, which forms the floor of the cave. Upon this is a slight covering of earthy matter, with here and there patches of charcoal; a few human bones and fragments of coarse ancient pottery have been observed. Upon breaking through the sparry floor the ossiferous earth is

* In the south-east of England fossil bones of elephants, &c. in the "drift" are common; see Murchison's paper on the flint-drift, Journ. Geol. Soc. vol. vii. A fissure in the Kentish Rag at Boughton Malherbe, near Maidstone, contained the jaw and some bones of a hyena, which are now in the Museum at Oxford; Mag. Nat. Hist. vol. ix. p. 593.

† See British Fossil Mammalia, p. 174.

exposed; and, *imbedded with the fossil bones*, several flint-knives with arrow- and spear-heads of flint have been discovered. These stone instruments are of the same kind as those found in the tumuli of the early British tribes, and unquestionably belong to the same period. This fact has given rise to much curious speculation, but the arguments I shall presently bring forward, when speaking of a similar collocation of works of art and human bones with those of the extinct cavern-animals, will, I conceive, show that the data hitherto obtained do not warrant the inference that these relics were contemporary. Kent's Hole, Banwell Cave, and all the ossiferous caves I have examined in England, appear to have been mere rents or fissures in limestone-rocks, which were filled with drift, while submerged in shallow water; and the carcasses of land-animals may have been floated in by the subaqueous currents. As the bones, though broken, are rarely water-worn, and the fragments even retain their sharp edges, the bones must have been more or less protected by muscles and skin: the extreme freshness of many of them (especially in Banwell Cave) supports this opinion. Upon the elevation of the land, these fissures were raised above the water, and gradually drained, during which period the formation of stalactite commenced from the percolation of water through the superincumbent beds of limestone. When Kent's Cave was accessible, and before the formation of the floor of stalagmite, some of the wandering tribes of the early Britons may have prowled into the recess, or occasionally sought shelter there; and stone implements, bones, or any hard substances, left in the cave, would soon sink a few feet in the soft ossiferous mud, and become hermetically sealed up, as it were, by the stalagmitic deposit.

From what has been stated, we learn that our wastes and forests were once inhabited by extinct herbivora and carnivora, belonging to genera of which the recent species are almost entirely restricted to southern climates; that some of the caves were tenanted by successive generations of bears, wolves, &c.; that the hyenas, according to their peculiar habits, dragged into their dens the creatures which they killed or found dead, and devoured them at their leisure;—that subsequently all these races were annihilated, except the few allied species which still inhabit the European continent and islands. In England, the only living representatives of the three families of carnivora which swarmed in

these latitudes during the Mammoth period, are the *Fox*, of the dog tribe; the *Wild Cat*, of the feline order; and the *Badger*, of the bear tribe.*

40. DISEASED BONES OF CARNIVORA FOUND IN CAVES.—Among the bones found in the caves of Germany are many in a condition which must have resulted from accident or disease. In some there has been a formation of new bony matter to repair fractures; in others there is anchylosis, or adhesion of the joints from inflammation; while in some the effects of caries, or decay of the bones, the result of tedious and painful diseases, are apparent. Others have a light and spongy character, and are very fragile, which must have arisen from a want of energy in the nutritive system, in consequence of a scrofulous affection.†

41. HUMAN BONES AND WORKS OF ART IN CAVERNS.—Not only in the caverns of England, but also in those of France and Germany, human bones and fragments of ancient pottery have been found. As mankind in an uncivilized state commonly inhabit caves, traces of their having occupied recesses, which had previously been the retreat of wild animals, might be expected. But as bones of extinct species occurred with these relics of man, it was assumed that they were coeval with each other; more accurate observations have, however, rendered it probable that the human remains were introduced at a later period. We have historical proof that the early inhabitants of Europe often resided or sought shelter in caves. Thus Florus records, that Cæsar ordered the inhabitants of Aquitania to be enclosed and suffocated in the caverns to which they had fled for safety ‡ Many tribes of the Celtic race occupied these subterranean

* British Fossil Mammalia.

† Professor Walther, on the antiquity of diseases of bones; see Professor Jameson's Cuvier's Theory of the Earth. Edin. 1827.

‡ A horrible and atrocious cruelty, which the French, of the nineteenth century, have not scrupled to perpetrate in Algeria!

retreats, not only as a refuge in time of war, but also for shelter from cold, and as magazines for their corn and for the produce of the chase, and as places of concealment for the animals they had domesticated. The bones of such of these people as perished, or were buried in the caverns, would become blended with the mud, gravel, and debris of the animals already entombed; and a stalagmitic paste might in some places be formed by the infiltration of water, as at Bize, and cement the whole into a solid aggregate. In concretionary masses of stone of this kind, containing bones of the bear and other extinct species, human bones, fragments of pottery, terrestrial shells, and bones of animals of modern times may therefore be associated.* Such are the contents of numerous caves, and this explanation shows how they may have been accumulated.†

42. OSSEOUS BRECCIA, OR BONE-CONGLOMERATE. — The facts we shall next examine are even more extraordinary than those already described; for the fossil remains are not imbedded in gravel or clay, or collected together in caves, but occur in fissures of limestone, over an area of many hundred leagues, and in rocks and islands very remote from each other. The limestone presents but little variety, the substance in which the fossils are enveloped is everywhere

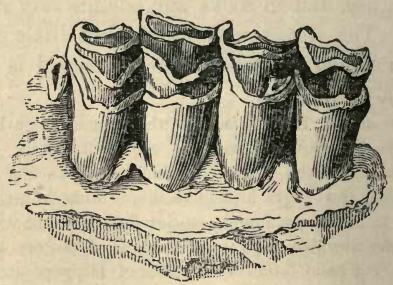
* Memoir by M. Desnoyer.

† The femur of the Bear is so like the human thigh-bone, as to be readily mistaken, without due caution; see Prof. Owen, British Mammalia, p. 96; in which the distinctive characters of each are pointed out.

Within the last few years human teeth and some human skulls have been reported to have been found associated with elephantine remains in the gravel of the Swabian Alps; and remains of pottery, &c. have been recorded as having been found with bones of Hippopotamus and Mammoth in the Aire Valley, near Leeds; there are other evidences, of more or less value, tending to indicate the contemporaneity of man with some of the extinct Mammalia, and to establish a somewhat more remote date for his introduction upon the Earth than has hitherto been assigned to him. Still this greater antiquity, if established, would not remove the human race beyond the limits of the newer Phocene period.

the same, and the bones belong, with few exceptions, to similar species of animals. The rocks in which they occur have been shattered in every direction, and the fissures are filled, more or less completely, with what geologists term an osseous or bone breccia; that is, an aggregation of bones held together by a calcareous cement or paste, in the same manner as the conglomerated shingle near Brighton (p. 79); or, to exemplify its nature by a still more familiar illustration, the mixture of mortar, pebbles, &c. which is employed in masonry, and called concrete.

This cement is of a reddish brown colour, and much resembles common brick, while the bones are beautifully white, and in many instances have their cavities lined with spar. In some examples the bones have undergone but little change; in others, the cells of the cancellated structure are filled with calcareous matter. The specimen before us (*Lign.* 32) is from Gibraltar, and contains two teeth and fragments of bone of a ruminant. The breccia in which the teeth are imbedded is now a compact limestone; it is of a



LIGN. 32.—TEETH OF A RUMINANT IN OSSEOUS BRECCIA, FROM GIBRALTAR.

dull red colour, mottled with white, and susceptible of a good polish. This osseous breccia occurs on the northern shores

of the Mediterranean; in the rock of Gibraltar; at Cette, Nice, and Antibes; in Dalmatia, and in the isles of Cerigo, Corsica, &c.; and in Sicily, Sardinia, and many parts of Germany. Each of these localities presents highly interesting examples of the objects of our present inquiry.

43. THE ROCK OF GIBRALTAR.—As the rock of Gibraltar, so well known from its historical and political importance, affords a good illustration of the phenomena under review, I shall, for the sake of brevity, confine my observations to that celebrated spot. Gibraltar is situated on the Spanish side of the Mediterranean, being united to the mainland by a narrow isthmus, which is a mere bank of consolidated sand, about three-fourths of a mile broad, and only eight or ten feet above the level of the sea. The rock stands on the western extremity of the area in which the osseous breccia occurs, and its greatest altitude is about 1350 feet. It is in great part composed of strata of compact, bluish-grey marble, of the oolitic period, and which, like most extensive limestone masses, is cavernous. The principal cavern, called St. Michael's, contains stalagmites and stalactites, which when polished are of great beauty. The fissures intersecting the rock, as well as those in some of the caves, are partially filled up with a calcareous concretion, of a reddish-brown colour, which in some parts is a mere earthy mass, but in others is highly indurated. The bones are commonly in a broken state, and but seldom water-worn; and the fragments of limestone with which the fissures abound are also angular, and have evidently, like the bones, fallen into the crevices at different periods, and been gradually incrusted and conglomerated by calcareous infiltrations. Snails and other land-shells of the existing species of the country often occur impacted in the solid breccia; and as the stalactitic concretion is constantly going on, some masses contain recent terrestrial shells unmixed with bones.

The cementing material is very similar in the different

localities where the breccia has been observed; namely, at Cette, Nice,* Antibes, &c., in Dalmatia and Sardinia. The animal remains of the breccia are referable to several species, some of which are recent, and others probably extinct, of deer, antelope, rabbit, rat, mouse, &c. Bones of birds and of lizards have been discovered at Cette; and of lemmings,† and of the *lagomys*,‡ which now only exists in Siberia: it is but rarely that traces of carnivora are observed.

No one can fail being struck with surprise at the occurrence of these isolated yet analogous phenomena, which surround the great basin of the Mediterranean; rocks of a uniform character, fissured and broken, their rents filled up with similar materials, and with the remains of the same species of animals. The occurrence of species either extinct, or no longer inhabiting the same latitudes (as the *lagomys*), refers the period of the existence of these animals to the epoch of the mammoths and mastodons; and the absence of marine remains, and of the usual abrading effects of water, shows that the breccia was formed on dry land, and not beneath the sea. The rational explanation of these facts appears to be that which assumes the original union of these distant rocks and islands into a continent, or large island, that, like Calabria, was subject to repeated visitations of earthquakes; and that the animals which inhabited the country fell into the fissures thus produced, and were preserved by the calcareous infiltrations that were constantly in progress. Subsequent convulsions and denuding agencies severed the country into rocks and insular masses, of which catastrophes the osseous conglomerates are the physical and only records.

* See an interesting memoir on the Geology of the Environs of Nice, by Sir H. De la Beche: Geol. Trans. 2nd Ser. vol. iii. p. 171.

† Lapland marmot.

‡ Signifying hare-rat; a small animal which forms a link between the hare and the rat.

44. Osseous breccia of Australia.—Caves and fissures filled with osseous breccia, of the same nature as that above described, have also been discovered in New Holland, to the westward of Sydney, near the banks of the Macquarrie river; and it is not a little remarkable, that even the red ochreous colour of the European conglomerates prevails; the bones, however, belong to animals wholly distinct from any noticed in the preceding examples. Some of them are of living, others of extinct species, but almost all are referable to marsupial animals, as the *Kangaroo*, *Wombat*, *Dasyurus*, &c. A portion of a large bone, found in a cave, is said to belong to the hippopotamus, and another fragment to the mastodon, but this requires confirmation; it is, however, a subject worthy of attention, since the kangaroo is the largest animal now known in those regions. The fact that the fossil mammals hitherto discovered in Australia are marsupial, that is, are of the same class as those which carry their young in a pouch—a type of organization which is the peculiar feature of the existing Australian fauna—is of great interest, for it proves that the present zoological character of the country has prevailed from a very remote period.

45. Retrospect.—I must now bring to a close this survey of the ancient superficial deposits—those accumulations of alluvial debris which, taken as a whole, are referable to a far more remote period than those which strictly belong to the human epoch; although the ancient pass by insensible gradations into those of comparatively recent origin.

In the former discourse I found it necessary to refer to the discoveries of Astronomy, to elucidate the earliest physical conditions of our planet; in the present I have summoned Comparative Anatomy to our aid, and have endeavoured to point out the mode of induction pursued by the paleontologist in his inquiries into the fossil remains of animal organization, and by which he is enabled to call forth from their rocky sepulchres the beings of past ages, and,

like the fabled sorcerer, give form and animation to the inhabitants of the tomb.

From the facts that have been reviewed in the course of this Lecture, the following inferences result.

First—that the extinction of certain forms of animal organization has extended throughout the period comprehended in our present researches. We have traced its influence from the partial extirpation of certain existing forms, to the entire annihilation of many species and genera that once were contemporary with man; as well as to those which lived, and became extinct, antecedent to all traces of the human race.

Secondly—that, while in the modern marine and fluviatile deposits the remains of existing species of animals, and of man and his works, are entombed, in the ancient alluvial sediments those of large extinct mammalia are chiefly imbedded, and no vestiges of human remains have been discovered.

Thirdly — that the bones principally belong to extinct mammalia, related to the elephant, hippopotamus, sloth, horse, deer, &c.; and to the bear, hyena, tiger, and other carnivora; and with these are associated the remains of recent species.

Fourthly—that in the period immediately antecedent to the present state of the earth's surface, the dry land teemed with large herbivorous animals, which roamed through the primeval forests, unmolested, save by beasts of prey. Numerous species and entire genera have since been swept away from the face of the earth,—some by physical revolutions, others by a gradual decadence,—while many have been exterminated by man.

Lastly—that the various deposits in which these fossils are imbedded, whether formed in the beds of lakes, rivers, or estuaries, have been elevated above the level of the waters and become dry land at a comparatively recent period, and

now constitute fertile countries, supporting busy communities of the human race.

I have thus endeavoured to interpret one chapter in the ancient physical history of our planet, and explain the records of one epoch in geological chronology. We have entered upon the confines of the past, and already we find ourselves surrounded by an innumerable population of unknown types of being,—not as dim and shadowy phantoms of the imagination, but in all the reality of form and structure, and bearing the impress of the mighty changes of which they constitute the imperishable memorials. We have witnessed the effects of repeated changes in the relative level of the land and water,—have seen that our present plains and valleys were submerged beneath the ocean, at a period when large mammalia, apparently unrestricted by existing geographical limits, were inhabitants of regions which are now no more—and we have obtained additional proof that—

> New worlds are still emerging from the deep,
> The old descending in their turn to rise!

Even in this early stage of our progress, we have conclusive evidence of the extinction of whole tribes of animals, alike admirably adapted to the conditions in which they were placed, as the races which have survived. And it is most gratifying to the geologist to find, that this fact, which but a few years since was received with hesitation by most, and condemned and rejected by many, is now adduced by the moralist and divine, as affording new and striking proof of the wisdom and overruling providence of the Eternal.*

* See Dr. Buckland's Bridgewater Essay.

LECTURE III.

1. Introductory. 2. Mineral composition of Rocks. 3. Crystallization. 4. Stratification. 5. Displaced Strata. 6. Veins and Faults. 7. Chronological Synopsis of the Strata. 8. Geology of England. 9. Post-tertiary deposits. 10. Tertiary Formations. 11. Classification of the Tertiary. 12. Fossil Shells. 13. Lithological Characters of the Tertiary. 14. Subdivisions of the Tertiary System. 15. Upper Tertiary or Pliocene. 16. Erratic Boulders. 17. Pliocene beds of Sicily. 18. The Crag. 19. Miocene or Middle Tertiary. 20. Eocene or Lower Tertiary Deposits. 21. The Paris Basin. 22. The London Basin. 23. The Isle of Sheppey. 24. Bagshot Sand. 25. Phenomena of Springs. 26. Artesian Wells. 27. The Hampshire Basin. 28. Alum Bay. 29. London Clay of Hampshire. 30. Freshwater Tertiary of the Isle of Wight. 31. Organic Remains of the Eocene Strata. 32. Amber. 33. Zoophytes of the Tertiary. 34. Shells of the Tertiary. 35. Fossil Nautilus. 36. Nummulites. 37. Foraminifera. 38. Crustaceans and Fishes. 39. Tertiary Reptiles. 40. Tertiary Birds. 41. Fossil Mammalia of Paris. 42. Palæotheria and Anoplotheria. 43. Fossil Monkeys. 44. Tertiary Deposits of Aix. 45. Fossil Insects. 46. Fossil Fox of Œningen. 47. Fossil Fishes of Monte Bolca. 48. Tertiary Volcanos of France. 49. Extinct Volcanos of Auvergne. 50. Crater of the Puy de Dome. 51. Mont Dore. 52. Lacustrine Strata of Auvergne. 53. Successive Epochs of Mammalia. 54. Survey of Geological Phenomena. 55. Excavation of Valleys by running Water. 56. Extinct Volcanos of the Rhine. 57. Brown Coal Deposits; the Loess. 58. Tertiary of Europe and North America. 59. Altered Tertiary of the Andes. 60 Saliferous Deposits. 61. Retrospect. 62. Concluding Remarks.

1. Introductory.—Although it is my object in these Lectures to present a general view of the philosophy of Geology, and render the examination of geological phenomena subservient to an exposition of the laws which the Divine Author of all things has established for the renovation, maintenance, and government of the organic and inorganic kingdoms of Nature, I must enter somewhat in detail on the nature and distribution of the materials of which the crust of the earth is composed. For based as Geology is upon observations of the various physical changes which are now taking place on the surface of our globe, and on investigations of the natural records of similar changes in periods antecedent to all human history and tradition, the

minerals and fossils are the alphabet, the rocks and mountains the volume, by which the student of this interesting department of science must learn its important lesson. But to those who cannot examine Nature in her secret recesses, or accompany an experienced teacher to the valleys or the mountain-tops, lectures illustrated by specimens and drawings afford, perhaps, the best substitute for the more efficient and interesting mode of instruction.

That we may obtain a clear and comprehensive view of the vast field of inquiry that lies before us, artificial classifications are necessary in this, as in other departments of science; and, without assuming that the arrangement in which the various deposits are grouped by modern geologists may not require considerable modification as new facts are brought to light, I will place before you a tabular view of the formations, or systems of deposits, in their presumed chronological order. At the same time it must be borne in mind, that all arrangements of this kind necessarily involve arbitrary distinctions; and that it may possibly hereafter appear, that we have in some instances classed as general what are but local phenomena, and have grouped together in one system strata which further investigations may show to be distinct formations, separated from each other by vast periods of time. It must too be admitted, that there are not in nature those strict lines of demarcation between one system of strata and another, which, for the convenience of study, have been adopted. For, though the limits of certain formations may be clearly defined in one region, in other and distant countries there may be an insensible passage from one system to the other. In short, both in the organic and inorganic kingdoms of nature, in proportion as our knowledge is increased, and our views enlarged, the harmony and unity of nature become more and more manifest; the apparent breaks in the chain of causation exist only in our imperfect conceptions. These considerations

will not, however, affect those leading principles of Geology which it is my present endeavour to render familiar to the intelligent but unscientific inquirer.

In pursuance of this object we will first take a general view of the nature of the mineral substances which enter into the composition of the crust of the earth, and briefly notice the laws which regulate the deposition of sedimentary detritus in the beds of rivers and in the depths of the ocean.

2. MINERAL COMPOSITION OF ROCKS.—Every substance is composed of atoms of inconceivable minuteness, held together by a principle termed attraction or cohesion, and which is probably a modification of that influence which, as it exists under certain conditions in inorganic substances, is called electricity, galvanism, or magnetism, and, in organized beings, nervous influence.* The different states of solidity, fluidity, and vapour, in which every material body may exist, were exemplified in a former lecture, and we need only remark, that of the substances which in the present state of chemical knowledge are considered simple or elementary, about sixteen constitute, in their various combinations, by far the largest amount of all organic and inorganic matter. Of these, eight are non-metallic; viz. *oxygen*, *hydrogen*, *nitrogen*, *carbon*, *sulphur*, *chlorine*, *fluorine*, and *phosphorus;* the first four are almost always found in combination. *Oxygen* constitutes one-fifth part of the atmosphere, and eight-ninths in weight of water, and a large proportion of every kind of rock. *Hydrogen* makes up the remaining portion of water; and *Nitrogen* four-fifths of the atmosphere. *Carbon* is the chief constituent of animal and vegetable structures, and is only found pure in the diamond.

* See a masterly "Essay on the Correlation of Physical Forces," by W. B. Grove, Esq. F.R.S. London, 1846.

There are also six metallic bases of alkalies and earths; namely, *silicon*, which, when united with an equivalent of oxygen, forms quartz, or flint, the basis of nearly half the rocks that compose the crust of the earth; *aluminium*, *potassium*, *sodium*, *magnesium*, and *calcium;* and two, the oxides of which are neither earths nor alkalies, namely, *iron* and *manganese*. The principal remaining metallic substances, viz. *copper*, *lead*, *zinc*, *arsenic*, *silver*, *gold*, &c. are comparatively unimportant in a geological point of view.

The sedimentary rocks are in a great measure composed either of lime, silex, or argillaceous earth; and accordingly as these substances predominate, the masses possess what in mineralogical language is recognised as a peculiar fracture, which is distinct in each. Thus, if I take this piece of flint and break it at random, it presents a glassy or *conchoidal* fracture, and every fragment has a sharp cutting edge; and subdivide it as I may, each portion retains the same character: but if I break this block of chalk, the edge is not sharp, but blunt and dull, exhibiting what is termed an *earthy* fracture. Again, if I shiver to pieces by a blow of a hammer this calcareous spar, every fragment partakes, more or less distinctly, of a rhomboidal form; so true is the remark, that we cannot break a stone but in nature's joinings. Slaty cleavage will be described in the sequel.

3. Crystallization.—Crystallization may be defined as a methodical arrangement of the particles of matter according to fixed laws.* For example, there are nearly 500 varieties of crystallized carbonate of lime, each crystal being composed of millions of atoms of the same compound substances, and having one invariable primary form—that of a rhomboid. Mechanical division is incapable of altering this arrangement; break the fragments as we may, we can only

* The definite or mathematical proportions in which substances unite, both as to weight and volume, is a subject of the highest interest, but which does not come within the scope of the present inquiry.

separate them into a rhomboidal figure; nor can this condition be altered except by chemical decomposition. If we pursue the investigation, we find by analysis that every atom of these crystals consists of lime and carbonic acid, each of which is made up of innumerable molecules. "Lime and carbonic acid are also themselves compounds, lime consisting of a metal called calcium and oxygen; and carbonic acid, of carbon and oxygen. Thus these ultimate particles of calcium, carbon, and oxygen form the indivisible atoms into which all the secondary crystals of lime may be reduced." *

4. STRATIFICATION.—Having previously shown that the disintegration and solution of the most refractory and apparently indestructible substances may take place from the conjoined effects of mechanical and chemical agency, we proceed to the consideration of the manner in which the debris of the ancient lands and the accumulations in the seas have been converted into the rocks and strata that form the existing islands and continents. The formation of beach and sand, and the deposition of mud and clay in layers or strata, and the subsequent consolidation of these materials into rocks, have already been explained. And here let me remind you, that *strata* are successive layers of detritus spread over each other in such manner as to allow of the partial consolidation of one bed before the deposition of another upon it; and a rock is said to be *stratified* when it presents the appearance of such divisions. Chalk-cliffs and sandstone and limestone quarries afford illustrations of this structure. The original direction of these layers must have been nearly horizontal, for this obvious reason, that in their original state of unconsolidated mud or sand they must have been more or less uniformly spread over the sea-bottom on which the water deposited them; and, although they might partake of the

* Dr. Buckland's Bridgewater Essay.

inequalities of the depressions in which they were deposited, yet this cause would not affect their general distribution. The strata when accumulated in very thin layers, resembling the seams formed by the leaves of a closed book, are termed *laminæ;* a character that commonly prevails in fluviatile or river deposits: thus the shales, clays, and sandstones of Tilgate Forest are laminated, and often bear the impress of the waves which have flowed over them (see p. 61).

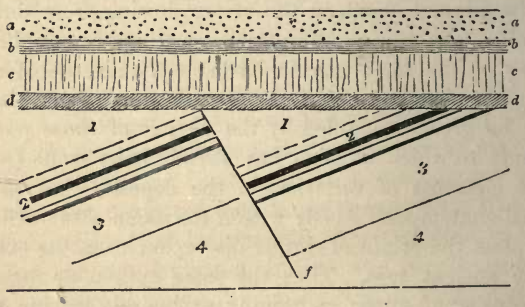
The contemporaneous beds formed in the same oceanic basin, though often maintaining a general character over very extensive areas, must nevertheless vary considerably. At the present moment, the rivers flowing from different latitudes into the existing seas must necessarily be producing in the same marine basin accumulations of a very dissimilar character; and the distribution of the detritus must be greatly modified by the agency of those powerful currents to which allusion has already been made (p. 70). These elements of variation in the deposits that may be formed contemporaneously within the same ocean-bed serve to explain the origin of similar discrepancies in the contents of the ancient seas. Thus the same system or formation may consist of strata containing exclusively marine shells, corals, fishes, &c., intercalated with layers of clays and sands abounding in lacustrine shells and plants and the remains of terrestrial animals and vegetables: the former being strictly of *marine*, and the latter of *fluvio-marine* origin; in other words, consisting of deposits brought into the sea by river-currents loaded with the detritus of the land.

The oolitic system of Yorkshire affords examples of these alternations of marine and fluvio-marine strata.

5. Displaced strata.—But, although the sedimentary strata have originally been deposited in horizontal layers, this arrangement has subsequently been disturbed by expansive internal forces, which have occasioned the elevation of some areas and the depression of others; and hence the

strata have often been broken up, and thrown into every direction, from a slight degree of inclination, to a vertical position.

It will therefore be requisite in this place to explain a few scientific terms which are frequently employed to express these phenomena; for, though it is my wish to abstain as much as possible from technical language, it cannot in all cases be avoided without incurring inconvenient circumlocution. Parallel layers of strata, placed horizontally upon each other, as *a*, *b*, *c*, *d*, in the annexed diagram (*Lign.* 33),



LIGN. 33.—ILLUSTRATIVE OF STRATIFICATION.

a, *b*, *c*, *d*, Horizontal strata in a conformable position with respect to each other, resting unconformably on the inclined strata, 1, 2, 3, 4.

1, 2, 3, 4, Strata in an inclined position, and severed and displaced by a fault, *f*.

are said to be *conformable;* but when strata are superimposed on others which lie in a different direction, as the series *a*, *b*, *c*, *d*, on the beds 1, 2, 3, 4,—as if a set of horizontal volumes were placed flat on the inclined edges of another series of books,—they are termed *unconformable.*

6. VEINS AND FAULTS.—But the strata have not only suffered change of position, they have also been rent and broken, and are traversed by cracks or fissures, which in

some instances are filled with bones, pebbles, and stalactitical concretions (p. 77), and in others with mineral matter and veins of metalliferous ores. The term *fault* is applied to those fractures and displacements which are accompanied with the subsidence of one part of a mass and the elevation of another. This is exemplified in the section of the carboniferous strata represented in *Lign.* 33, in which the seams of coal and other beds (1, 2, 3, 4) have been shifted to a higher level on the left hand, though both sides of the rock remain in apposition; *f.* marks the line of fault. Strata, in fact, may be compared with the layers of masonry in a building; beds of clay representing the mortar, and those of harder rocks the courses of brick or stone; while the fissures, veins, and faults are analogous to the cracks, sinkings, and displacements produced by the settling of different portions of the edifice after its erection.

7. CHRONOLOGICAL ARRANGEMENT OF THE STRATA.—In the alluvial beds of gravel, sand, and marl, containing the remains of the large herbivorous mammalia, which formed the principal subject of the previous discourse, but few indications of regular stratification are observable; the deposits for the most part consisting of materials that have been transported by rivers or currents, or drifted by icebergs, and accumulated in estuaries and bays, or spread along the shallows of sea-coasts. The vast series of ancient deposits we are about to examine are on the contrary composed of regularly stratified rocks, with occasional interspersions of fluviatile and alluvial debris, and intrusions of volcanic matter.

It is necessary to premise, that there are three elements of classification applicable to stratified rocks; namely, 1st, their minerals tructure; 2ndly, their order of superposition; and 3rdly, the nature of the organic remains which they contain: the following arrangement is in accordance with these principles. The terms by which the formations and

their subdivisions are designated generally express the predominant characters by which they are distinguished.

A CHRONOLOGICAL SYNOPSIS OF THE PRINCIPAL ROCKS AND STRATA.*

(*Commencing with the uppermost or newest deposits.*)

Fossiliferous Strata.

I. THE POST-TERTIARY. — Alluvial accumulations in rivers, lakes, and seas during recent times; together with the products of contemporaneous volcanic eruptions. This series is divisible into two groups, chronologically distinct: 1. the latest, termed the *Human* or *Modern*, comprising superficial deposits, characterized by the remains of man and his works, and of animals and plants contemporaneous with the human race: 2. (the Pre-historic) similar deposits formed immediately before the introduction of man upon the earth, and containing remains of shell-fish and other animals of still existing species, together with some that are now altogether extinct, and others that are no longer found alive in the localities where their remains occur.

II. THE TERTIARY EPOCH.—An extensive series, comprising many isolated groups of marine, fluvio-marine, and lacustrine deposits, containing remains of animals and vegetables of all the existing orders and families, and of many of the existing genera and species; and with these are associated numerous extinct species and genera of mammalia, reptiles, fishes, molluscs, &c.

Observations.—This epoch is divisible into three periods, the Later, Middle, and Earlier Tertiary; to the Later Tertiary belong those frequently superficial accumulations of loam, clay, drifted gravel, sand, and

* For the latest and best tabular view of the fossiliferous strata, the student must consult Lyell's Manual, 1855, p. 105.

boulders, in which with shells and bones of existing species of animals are associated those of the Mammoth, Gigantic Deer, and other extirpated genera; together with the bone-breccias and cave-deposits containing remains of extinct mammalia. The line of demarcation between the most ancient beds of this, and the most modern of the preceding epoch, cannot be strictly defined; and the separation can only be regarded as conventional: nor can the modern epoch be very definitely divided from the latest tertiary. In Europe, the elevation of the Alps appears to have been the grand physical event which marked the close of the tertiary period; for in all deposits of later age existing species have been met with.

The formations of the two earlier divisions of this epoch are assemblages of marine, fluvio-marine, and lacustrine strata, either isolated or alternating, and occupying extensive but defined areas. These beds consist of detritus accumulated during long periods in bays, gulfs, deltas, and lakes, and in the depths of the ocean. Intrusions of lava-currents, scoriæ, and other volcanic products occur in many of the tertiary formations. The zoological character of this epoch is the prevalence of terrestrial mammalia.

III. The Secondary Epoch.—An immense series of marine strata, with intercalations of fluvio-marine deposits, and at least one extensive delta. The most striking zoological characters of this epoch are the rare occurrence of warm-blooded animals, and the abundance of terrestrial and aquatic reptiles. The aggregate thickness of the strata is many thousand feet. The following are the principal subdivisions of the formations comprised in this class.

(1.) The cretaceous (or *Chalk*) formation.—Marine strata, with but few interspersions of terrestrial or fluviatile debris. In England, the soft white limestone termed "Chalk" forms the upper strata; marls and clays, the medial; and clays, sands, sandstones, and some limestones, the lower portion of the series. The strata abound in the remains of extinct species of zoophytes, mollusca, echinoderms, fishes, and reptiles. Drifted wood and some marine plants are, with but few exceptions, the only vegetable exuviæ found in this series in England; but at Aix-la-Chapelle and elsewhere remains of land-plants are numerous.

Observations.—The strata comprehended in the term *Cretaceous Formation*, though differing essentially in their lithological constituents, so far correspond in the nature of their organic remains, as to prove that the whole were formed under the same general conditions; in other words, that the sea and land, and their inhabitants, underwent no essential change during the vast periods in which these deposits were accumulated; the entire series therefore constitutes, in geological language, but one formation. With but a very few exceptions, no vestiges of existing species of animals have been detected.

(2.) THE WEALDEN AND PURBECK FORMATION.—A series of fluviatile deposits of great thickness and extent, with scarcely any interpolations of marine detritus. The lithological characters are alternations of clays, limestones, sands, and sandstones, many of them rich with freshwater shells and crustaceans. The organic remains peculiar to this formation are some small mammalia, abundant remains of enormous land and aquatic reptiles, river-shells, and minute entomostraca; also insects, coniferous trees, cycadeous plants, ferns, and other terrestrial vegetables.

Observations.—This remarkable series presents the most unequivocal example of an ancient delta, or assemblage of fluviatile and estuarine deposits, hitherto observed. The strata exhibit throughout the character of river-detritus, that has been accumulated either in a vast inland lake, which received the drainage of an extensive country, and had but a restricted communication with the ocean, or in the lagoons of a great river-delta. The Wealden extends over the whole of the south-east of England and a great part of the north of Germany.

(3.) THE JURASSIC OR OOLITIC FORMATION.—A formation of great thickness and extent, consisting of several groups of marine limestones and clays, which abound in extinct marine shells, corals, echinoderms, crustaceans, fishes, and reptiles; with intercalations of fluvio-marine strata, in which are remains of terrestrial reptiles, insects, and plants, and of *three genera of small extinct mammalia.* Beds of coal and lignite, of considerable extent, occur in some parts of the system.

(4.) THE LIAS.—Marine clays, shales, and limestones, full

of shells, crinoidea, crustaceans, fishes, and extinct reptiles; with fluvio-marine beds, containing insects, minute crustaceans, lignite, trunks and leaves of coniferous trees, and cycadeous plants.

Observations.—The Oolite and Lias, though conveniently distinguished by certain species of shells, &c., must be regarded as but one natural series or group of deposits, formed in the bed of an ocean of great extent, into which numerous streams transported the debris of the land, and its inhabitants. Two genera of marine reptiles, *Ichthyosaurus* and *Plesiosaurus*, swarmed in the Liassic sea, and, together with the *Pliosaurus*, lived on throughout the Oolitic period.

(5.) The Triassic (*New Red*) formation.—A group of variegated, blue, yellow, and red marls, abounding in gypsum and salt; with sandstones, limestones, and conglomerates, for the most part coloured red by peroxide of iron. Fossils are not abundant, but some peculiar shells, corals, crinoidea, reptiles, and coniferous plants characterize the series, which is, for the most part, of marine formation.

Observations.—This group is the grand depository of rock-salt in England. In Germany the strata form a triple series (whence the name *Triassic*) of variegated marls, limestones, and sandstones, which contain peculiar fossil remains. The separation of these deposits from the red marls of the next division has been made in consequence of certain genera and species of animals, which abound in the more ancient rocks, being entirely absent in the Triassic and all the subsequent formations. The Triassic is therefore, at present, regarded as the lowermost, or base-line, of the formations comprised in the secondary epoch; the faunas and floras of the older strata being entirely distinct from those of the secondary.

IV. The Palæozoic or Primary Epoch.—Under this general term are comprised all the fossiliferous strata more ancient than the Trias, and the organic remains of which, as the name indicates, belong exclusively to species or genera that are wanting in all the newer formations.

(6.) The Permian (*Magnesian Limestone*) formation.—A series of marine strata, consisting, in England, of lime-

stones charged with a large proportion of magnesia, conglomerates, marl-slates, red marl, and sandstones. These contain peculiar shells, fishes, and reptiles.

Observations.—This group of deposits was formerly named the *Lower New Red Sandstone*, or *Magnesian Limestone;* but, as either of these terms is ambiguous, that of Permian (first suggested by Sir R. Murchison, from the large development of the series in the government of Perm in Russia) is now generally adopted. In this group are included all the deposits that intervene between the Triassic above and the Carboniferous systems below. The Permian types of animal and vegetable life are nearly allied to those of the Carboniferous formation. Remains of reptiles occur, and, with few exceptions, are the most ancient of this class of animals.

(7.) THE CARBONIFEROUS FORMATION.—Sandstones, grits, shales, clays, and layers of ironstone, alternating with beds of coal, form the upper series;—limestone and flag-stone, with layers and nodules of chert, abounding in marine shells, crinoidea, and corals, constitute the lower division of this extensive group of deposits; the total thickness of which is many thousand feet. The coal-strata are remarkable for the abundance and peculiarity of the terrestrial trees and plants, of which they are almost wholly constituted; remains of reptiles, fishes, insects, and crustaceans of extinct families have been found in this formation.

Observations.—These strata, so interesting to the botanist from the richness and peculiarity of their fossil flora, and to mankind in general for the inexhaustible supply of fuel which they yield, appear for the most part to have been deposited in salt water; for the beds of coal are generally associated with marine shells, corals, &c.; there are, however, local intercalations of layers of fresh-water shells. The flora of the coal is the most striking feature of this system of deposits.

(8.) THE DEVONIAN (*Old Red*) FORMATION.—An assemblage of quartzose grits, sandstones, marls, and conglomerates, largely charged with peroxide of iron (which imparts to the whole a dull-red colour), with beds of coralline marble and laminated micaceous sandstones; this formation was

formerly, from its colour, denominated the Old Red sandstone, in contradistinction to the New Red. Shells, corals, fishes, crustaceans, and cephalopoda, of peculiar species and genera, are the prevailing and characteristic organic remains.

Observations.—The term Devonian, which has been substituted for that of Old Red sandstone, as being more precise, is derived from the geographical development of this group of rocks in Devonshire, England. The red conglomerates, which constitute a well-marked lithological character in some localities, consist of water-worn fragments of slate with quartz-pebbles, cemented together by red sand and marl, and have evidently resulted from the destruction of ancient slate-rocks; they are in some instances mixed up with volcanic ashes and scoriæ. Beautiful coralline marbles occur in South Devonshire, and in Scotland and other localities fishes of a very remarkable conformation abound, belonging to genera unknown in any other system.

(9.) THE SILURIAN AND CAMBRIAN FORMATION.— Marine limestones, sandstones, shales, and calcareous flagstones, abounding in shells, cephalopoda, corals, and crustaceans (especially of the extinct family of Trilobites), constitute the upper division of this important and extensive system of marine deposits. Traces of fuci are almost the only known vegetable remains.

A largely developed series of slate-rocks and conglomerates, several thousand yards in thickness, and often intercalated with igneous rocks, the uppermost beds containing shells and trilobites of the same types as those above, are included in the lower division of this great formation.

Observations.—This system is entirely of marine origin, and many beds are aggregations of corals, shells, &c. cemented together by calcareous matter. The organic remains are numerous, and afford characters by which the system is conveniently subdivided into two groups; but only one general organic type prevails throughout. The lowermost beds contain but few fossils, except Lingulæ, and insensibly pass into sedimentary deposits in which no traces of organic existence, except annelid-markings, have yet been discovered. This most ancient formation of

the Palæozoic system was studied by Sedgwick and Murchison, for the most part contemporaneously, in the Lake District, Wales, and Shropshire. Murchison divides the formation into Upper Silurian, Lower Silurian, and Bottom-rocks; but the Cambrian of Sedgwick includes both the lowest unfossiferous rocks and the Lower Silurian of Murchison.

Hypogene Rocks.

I. METAMORPHIC; or laminated crystalline rocks.

Observations.—These rocks are presumed to be sedimentary deposits that have been metamorphosed or changed in mineral structure from long exposure to a high temperature under great pressure; by which their constituent substances have passed into new combinations, and all traces of any organic remains they may have contained entirely obliterated. The name *Hypogene*, or *nether-formed* rocks (suggested by Lyell *), refers to the condition under which these rocks are supposed to have originated. They are subdivided into two not very distinct groups:

(1.) Mica-slate, clay-slate, chlorite-slate, quartz-rock, hornblende-schist, and crystalline limestone.
(2.) Gneiss, quartz-rock, &c., alternating with clay-slate and mica-schist.

Observations.—The *mica-schist* is a slaty rock, compesed of mica and quartz, and often passes insensibly into gneiss on one hand, and into clay-slate on the other. *Gneiss* is formed of mica, quartz, and felspar, has a laminated structure, and often occurs in stratiform masses.

II. PLUTONIC; or amorphous crystalline rocks.
Granitic Rocks; comprising Granite, Syenite, Porphyry, Felspar-rocks, Greenstone, and other Trap-rocks.

Observations.—The well-known rock termed granite, which, like gneiss, is composed of mica, quartz, and felspar, is not stratified or disposed in layers (though often graduating into gneiss), but occurs either in amorphous masses protruded through newer rocks, or in dikes and veins, which often traverse strata of all ages. The traps, porphyries, &c., included in this system, have the character of mineral masses which have been rendered crystalline by intense fusion, under great pressure, in the depths of the earth.

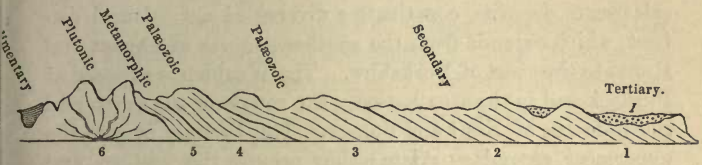
* From ὑπο, *under*, and γινομα, *I am born*; see "Manual of Geology," p. 9.

Volcanic Rocks.

(1.) Greenstone, Basalt, Toadstone, and other Trappean rocks :—products erupted from ancient volcanos.

(2.) Lava, Obsidian (or glassy lava), Tuff, Scoriæ, Pumice, Ashes, &c. :—products of modern dormant and active sub-aerial volcanos.

Observations.—In this class are placed the mineral productions of fire, or subterranean heat, ejected from beneath the surface, through fissures or rents, whether in ancient or modern times. These igneous materials are of all ages; they traverse alike the hypogene rocks and the sedimentary strata, as well as the most recent deposits.



LIGN. 34.—DIAGRAM OF THE RELATIVE POSITION OF THE ROCKS AND STRATA IN ENGLAND.

1. Tertiary strata. 2. Secondary. 3. Upper Palæozoic. 4. Older Palæozoic. 5. Metamorphic rocks. 6. Plutonic (granitic) rocks.

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8. GEOLOGY OF ENGLAND. — By an inspection of the Geological Map of England, *Plate I.*, it will be seen that the principal formations successively appear on the surface somewhat in their true chronological order (*Lign.* 34), as we pass from the eastern or south-eastern part of the Island to the west or north-west; as, for example, from the coast of Suffolk to Cardigan Bay, or from London to Liverpool. Thus, the Tertiary deposits are spread along the eastern and south-eastern maritime districts; and, in proceeding in a north-westerly direction, we successively travel over the Cretaceous, Oolitic, Triassic, Permian, Carboniferous, Devonian, Silurian, and Cambrian systems; and, lastly, metamorphic and crystalline rocks appear.

This distribution of the strata has imparted a peculiar character to the physical geography of England. The mountainous districts, which extend north and south along the western portion of England and Wales, from Cornwall to Cumberland, are formed by the elevated masses of the Metamorphic, Cambrian, and Silurian rocks. These are succeeded by a band of the Carboniferous, Permian, and Triassic strata, with a few intrusions of metamorphic and plutonic rocks, that stretches from the coast of Devonshire, through the midland counties by Leicestershire and Derbyshire, to Newcastle. On the south-east of this tract the Oolitic and Cretaceous formations, chiefly made up of argillaceous and calcareous deposits, constitute a diversified agricultural district, which extends from the southern shores of Dorset and Hants to the coast of Yorkshire. The Wealden is exposed at Purbeck and in the area between the ranges of the north and south downs of Kent and Sussex. The Tertiary overlie the uppermost secondary strata; they occupy the eastern and south-eastern maritime districts, and form the area on which stands the metropolis of England; they are covered in many places by the Drift and Alluvial debris which contain mammalian remains.

After this comprehensive view of the leading characters of the principal rocks and strata of which the present islands and continents are composed, we proceed to a more particular examination of the several formations in their natural sequence, or order of superposition.

9. POST-TERTIARY DEPOSITS.*—The formation of alluvial strata, and other superficial accumulations resulting from the operations of existing rivers and seas, whether the land and water had the same relative position they now hold, or whether the land was at a somewhat higher or lower position

* A corrected Table of the Tertiary and Post-Tertiary deposits of England is given in the Prefatory note of the 3rd Edit. of the Geology of the Isle of Wight, p. xiii.

relatively to the sea-level, is treated of in the first Lecture (§ § 19 to 60); and the occurrence of the remains of land-animals in such superficial deposits (as well as in similar accumulations of the next preceding period) is illustrated by numerous instances in the second Lecture.

10. THE TERTIARY FORMATIONS.—We now enter upon the consideration of the *Tertiary Formations*,—those ancient deposits of seas, rivers, and lakes which belong to the period immediately antecedent to that which is marked by the prevalence of remains of existing species of quadrupeds, and subsequent to the deposition of the uppermost secondary formation, the *Chalk*.

The discoveries of Cuvier and Brongniart, about thirty years since, in the immediate vicinity of Paris, first directed attention to the important series of strata now distinguished by the name of *Tertiary* (*see* p. 200). The extinct pachyderms whose bones abound in the gypsum-quarries of Montmartre were by the genius of Cuvier recalled, as it were, into existence, and the philosophers of Europe saw with astonishment whole tribes of unknown and extraordinary types of being disinterred from rocks and mountains which had previously been considered as destitute of scientific interest. Analogous strata, some of a marine, and others of a lacustrine and fluviatile character, were soon found to be spread over many parts of the continents of Europe and America; forming a series so extensive, and requiring such a lapse of time for its production, that the Chalk, hitherto regarded as comparatively of modern origin, is carried back to a period incalculably remote. The tertiary system may be said to constitute a series of strata which unites the present organic kingdoms with the past; for, while the most ancient contain species related to forms that occur in the secondary formations, the most recent insensibly glide into the modern deposits, and abound in fossil remains of living species of ani-

mals and plants, associated with many that are not now known to exist.

Sir C. Lyell has adopted a classification of the tertiary strata, founded on the relative proportion of recent and extinct species of animals which any given series of beds may contain; and as shells occur in most of the strata in great abundance, and in good preservation, he has selected these types of animal organization, as the distinctive characters of the principal subdivisions. Though in the present state of our knowledge this method is of great utility, it will probably require considerable modification; and, perhaps, must hereafter be altogether abandoned; for it cannot be doubted, that strata in which no recent species have yet been found may yield them to more diligent and extended researches; and the relative proportions of recent and extinct organisms may be found to occur in a very different ratio from that which is assumed as the basis of this arrangement.*

11. CLASSIFICATION OF THE TERTIARY.—According to this system the tertiary strata form three principal groups, each characterized by the relative proportion of the recent and extinct species of shells; and a nomenclature has been adopted expressive of the characters upon which the classification is founded. These divisions are as follow:—

1. THE PLIOCENE † (*signifying more new or recent*).—Tertiary strata

* This anticipation is already in some measure confirmed; for existing species have been found in the most ancient tertiary deposits: and several secondary shells, fishes, &c. in tertiary strata, and even living in the present seas. See Philippi, Quart. Journ. Geol. Soc. vol. ii. part 2, p. 17; and Pictet on the Diluvial Deposits of the Canton of Geneva. Some excellent observations on the paleontological relations of the tertiary and cretaceous deposits may be found in Mr. Prestwich's paper on the London Clay in the Geological Society's Journal, vol. x. p. 443.

† The Pliocene and Miocene are grouped together by some Continental geologists, under the term NEOGENE (*new-born*).

in which the shells are for the most part recent; containing about ten per cent. of extinct species; these beds are subdivided into the *newer* and *older pliocene*.

2. THE MIOCENE (*denoting less recent*):—containing a small proportion, about twenty per cent., of recent species of shells.
3. EOCENE * (*signifying the dawn of recent, in allusion to the first appearance of recent species*):—containing very few recent species; not more than three or four per cent.

The marine are in many instances associated with fresh-water deposits, and the general characters of the system are alternations of marine with lacustrine or fluviatile strata. The districts occupied by these beds in Europe are exceedingly variable in extent, as Lyell has shown in a very ingenious map of the tertiary seas;† and it appears certain, that during the tertiary epoch there were large areas alternately the sites of fresh-water lakes and inland seas, and that these transitions were dependent on oscillations in the relative level of the land and water.

12. FOSSIL SHELLS.—The geological evidence afforded by fossil remains has already been exemplified; but our remarks have hitherto in a great measure been restricted to the relics of terrestrial quadrupeds. The shells of mollusca, however, from their durability, often escape obliteration under circumstances in which all traces of the higher orders of animals are lost, and they become, therefore, of the utmost importance in the speculations of the geologist. In clayey sand-beds, they sometimes occur in a high degree of perfection; in mud and clay, in a fragile state; in some instances they are silicified; and many limestones are wholly composed of shells, cemented together by calcareous spar.

* Some of the Tertiary beds of Germany (Mayence, &c.) appear to be neither exactly of Eocene nor Miocene age, and have been separated by M. Beyrich as an intermediate series, with the name of OLIGOCENE (*slightly recent*).

† Principles of Geology.

Molluscous animals * are divided into *mollusca*,† properly so called,‡ which are covered with a single shell, as snails, periwinkles, &c.; and *conchifera*, || having a shell with two valves, as oysters, scallops, &c. The former are of a higher organization than the latter, having eyes and a distinct nervous system; the latter have neither eyes nor head, and are therefore called *acephala*.§ Some genera are herbivorous, living exclusively on vegetables; others are carnivorous; and many have a retractile proboscis, furnished with a rasp, by which they can perforate wood, shells, stone, and other substances. The shells of the carnivorous testacea are also generally provided with a channelled or grooved beak, for the reception of the fleshy syphon by which the sea-water is conveyed to the respiratory organs (*Lign.* 39, *fig.* 3, 4, 5); while the herbivorous have the opening of the shell entire (*Lign.* 40, *fig.* 3, 5, 6, 7). Some tribes are exclusively marine, others can only live in fresh water, while many are restricted to the brackish waters of estuaries. Their geographical distribution is also various: not only do certain genera affect distinct "marine provinces," and species even sometimes confine themselves to limited areas, ¶ but the mollusca have a certain *distribution in depth;* so that some are recognised as being peculiar to deep sea, some to shallows, and others as inhabiting the intermediate depths:** many exist in quiet, others in turbulent waters; some are gregarious, like the oyster, while others occur singly or in small groups. All these varieties of condition

* Medals of Creation, 2nd Edit. vol. i. chap. 11, p. 374. The student should consult Mr. Woodward's compact and most valuable "Manual of the Mollusca," for general and special information regarding both recent and fossil molluscan animals.

† Soft-bodied.

‡ Known also as *Encephala*, or molluscs with heads.

|| Shell-bearing. § Having no head.

¶ See Woodward's Manual of Mollusca, p. 349.

** Ibid. p. 439.

are more or less strongly evidenced on their shelly coverings, which may be regarded as their external skeletons; and the experienced conchologist is generally enabled, by the peculiar characters of the shell, at once to determine the economy and habits of the animal, and consequently the physical conditions in which it was placed.* In this point of view, fossil shells become objects of the highest importance to the geologist, since they are frequently the only indications of the circumstances under which deposits were accumulated.† I return from this digression to the consideration of the phenomena presented by the several groups of the tertiary formations.

13. LITHOLOGICAL CHARACTERS OF THE TERTIARY STRATA.—Excepting the boulder-clay of the glacial period (presently to be noticed), the superficial gravels and loams with elephantine and other remains, the cave-deposits of Kirkdale and elsewhere, also with bones of extinct animals,

* There is, however, a source of error that cannot always be guarded against: great changes are produced in shells by merely local influences, and these are often mistaken for specific distinctions. Professor E. Forbes, whose investigations have so beautifully elucidated many of the phenomena relating to the submarine distribution of the mollusca and other aquatic animals, affirms that many parts of the sea are too deep to admit of the existence of any animals or vegetables; and, therefore, that deposits of vast thickness, in which no organic remains can occur, may be forming in those profound abysses at the present time. Hence, we have no conclusive evidence that the so-called *azoic* strata were formed before the existence of animated beings; or that any unfossiliferous beds of later date were deposited in deeper water than many of the fossiliferous deposits. On the other hand, tides and currents, besides depositing the snails of the land in marine beds with or without remains of marine animals, may to some extent mingle the shells inhabiting one marine province with those of another; and the same agency may not only mix the remains of molluscs peculiar to one zone of depth with those that live in another, but in some instances may even transport organic remains from inhabited zones to the lifeless abysses of the fathomless ocean.

† See Medals of Creation, 2nd Edit. vol. i. p. 381.

and the osseous breccia already described (p. 185), the predominating characters of the tertiary system are alternations of marine beds with those of lacustrine and fresh-water origin. A large portion of the beds is arenaceous, with intervening strata of clay and marl. Shingles, the remains of ancient sea-beaches, abound in some localities, and often occur as a conglomerate or pudding-stone, as in Hertfordshire (p. 101); or as a ferruginous breccia, as at Castle Hill, near Newhaven, on the Sussex coast.* The ruins of the Chalk are everywhere recognisable in the immense beds of water-worn flints, which contain shells and zoophytes peculiar to the cretaceous system. Large erratic boulders and blocks of crystalline sandstone are of frequent occurrence on the chalk-downs, and have probably been derived from the upper beds of the Bagshot sand. In the vicinity of Brighton, blocks of ferruginous breccia are scattered over the surface of the Downs, and masses of quartzose sandstone, of a saccharine structure, occur at Falmer and in Stanmer Park: some years since there was a large rock of this stone in Goldstone Bottom near Brighton. In most of the gravel-beds around London there are numerous blocks of siliceous breccia and conglomerate.

In some of the tertiary series limestone predominates, and alternates with sands and marls of great variety and brilliancy of colour; beds of gypsum, and siliceous nodules resembling the flints of the chalk, also occur. Such are the leading lithological features of this system of deposits, which we will now examine more in detail.

The present distribution of the tertiary strata over Europe is in areas more or less well defined. In our own Island there are the so-called basins of London and Hampshire, the strata of which were originally united; and the remains of other series of beds in Yorkshire, Norfolk, Suffolk, Essex, &c. The metropolis of France is situated within the confines of

* Geology of the S. E. of England, p. 55.

a tertiary area; and in the southern and northern provinces of that country there are extensive tracts of similar deposits. In Auvergne, they are associated with lavas and scoriæ of ancient volcanic eruptions, and constitute a district of unrivalled geological interest. In the Sub-Apennines they are largely developed; and in other parts of Sicily and Italy they insensibly pass into vast beds of modern origin, which are still in progress of formation.

In the United States, tertiary marls, clays, and sands are spread over considerable areas between the Alleghany mountains and the Atlantic, resting upon sands and marls belonging to the chalk-formation. In Maryland and Virginia, there are extensive deposits of this class, remarkable for their organic composition, as we shall hereafter have occasion to notice.

14. SUBDIVISIONS OF THE TERTIARY SYSTEM.—The divisions of the Tertiary system, adopted by geologists, are concisely expressed in the following synopsis: *

I. PLIOCENE; or *Upper Tertiary.*	Fresh-water and marine strata, containing but a very few extinct species of shells. Abundance of existing species, indicating a marine fauna not essentially different from that which now prevails in the present seas.	Glacial drift of Britain, Northern Europe, and North America. Fluvio-marine beds on the eastern coast of England. Cave-deposits of Kirkdale, &c. Raised beaches of the Mediterranean. The Aralo-Caspian formations. Sub-Apennine deposits; and those of Palermo, and other parts of Sicily. The *Crag* of the maritime parts of Essex, Suffolk, and Norfolk, and of the Netherlands and Normandy.

* See Lyell's Manual of Geology, 1855, p. 105.

II. MIOCENE; or *Middle Tertiary.*	Strata containing from twenty to thirty per cent. of extinct species of shells. The temperature of the sea, as indicated by the shells, of a sub-tropical character.	Faluns of the Loire. Bolderberg beds of Belgium. The Sewalik Hills; also some deposits near Bordeaux, near Turin, in the Vienna Basin, and in Virginia; but none in England.
III. EOCENE; or *Lower Tertiary.*	Marine and fresh-water deposits; the recent species of shells amounting to scarcely more than five per cent. The prevailing forms indicate a marine temperature almost equal to that of the existing tropical seas.	The deposits of the tertiary basins of London, Hampshire, and Paris; also the lower portions of the tertiary series of the Netherlands and Belgium; and extensive deposits in central and eastern Europe, in Asia, and in North America.

15. UPPER TERTIARY, OR PLIOCENE.—When explaining, in the previous Lecture, the circumstances under which the remains of terrestrial quadrupeds occur in the superficial deposits, the nature and origin of those beds were briefly described. It is necessary, in this place, to offer a few remarks on the phenomena presented by the drift and other alluvial accumulations of the latest period of the tertiary epoch.

The drift * consists of beds of loam, sand, and gravel, variously distributed; being, in some instances, spread over extensive areas; in others, forming mounds, ridges, and hills of low elevation; in others, cresting the summits of abrupt and lofty escarpments: sometimes radiating, as it were, in broad streams from mountain-chains; in others, constituting

* Formerly called diluvium.

a series of terraces and platforms, as if originating in gradual and successive elevations of a sea-coast. The composition of these deposits is as various as their origin. They are generally made up of the detritus of rocks of all ages, promiscuously intermingled, and vary in condition from fine earth and sand, or gravel and pebbles, to large boulders and fragments of rock many tons in weight. They sometimes consist of the debris of the strata of the adjacent country, but frequently of rocks that are situated in distant regions.

It will be apparent to the intelligent reader, that deposits varying so much in mineral characters and structure must have been accumulated under very dissimilar conditions. Some are unquestionably ancient shingles or sea-beaches (*see* p. 112); others are sheets of detritus that have been formed along shallow coast-lines, or on the borders of rivers, lakes, deltas, and estuaries; others consist of ridges and mounds of debris heaped up by sudden deluges or powerful floods that have swept over low tracts of country, or by subaqueous currents, or waves of translation; and others have been produced by the agency of frozen water, either as floating icebergs, coast-ice, or glaciers. By the nature and state of the shells, bones, and other organic remains, when present, and of the gravel, pebbles, boulders, sand, clay, &c. of which the accumulation of drift or ancient alluvium may consist, the origin of the materials, and the age and character of the deposit, may be more or less satisfactorily determined.*

16. Erratic Boulders.—But there is one class of phenomena connected with these glacial accumulations which must not be passed over without comment. In many countries rounded and angular boulders of great size are very abundant, either imbedded in the superficial sands and gravel, or spread over them. Vast areas literally covered with boulders occur in many parts of Europe; enormous masses

* Lyell's "Principles of Geology" should be consulted for a full exposition of this subject.

of stone lying exposed on the surface of the ground, as bare as when left by the retiring waters, and appearing as—

> "Huge rocks and mounds confus'dly hurl'd,
> The fragments of an earlier world."

Many of these boulders are of such magnitude, as more properly to be termed rocks; being from twenty to forty feet high, and weighing many hundred tons.*

Connected with the boulders and beds of drifted gravel and other coarse detritus, is the occurrence of deep grooves, furrows, striæ, and scratches both on the sides of the boulders themselves, and on the upper surface of many rocks, and on the sides of such as flank narrow gorges and valleys, or form the slopes of hills and other inclined planes; appearances manifestly resulting from the passage of pebbles, grit, boulders, and angular fragments of hard stone, over exposed surfaces of rocks and strata; in some instances by the action of currents and floods, in others by glaciers and floating ice. In some countries the boulders are not far distant from their parent rocks, and their course and origin may be readily traced; but throughout a great part of Europe, Asia, and America, these water-worn masses must have been derived from very remote regions; and they are distributed in such manner, as to show that their transport could not have taken place under the existing geographical distribution of the land and water, but must have been effected when the present dry land was beneath the sea, and subaqueous currents and icebergs were in active operation.

* There is a large boulder in the plain near Mount Sinai, which monkish legends identify with the rock of Horeb, whence Moses, by a stroke of his rod, miraculously raised a stream of water for the parched Israelites. It is a block of granite, nearly twenty feet square, which has probably been derived from the neighbouring mountain.—Mr. Greenough's "*Critical Examination of the First Principles of Geology:*" a work abounding in facts and comments of the highest interest.

By the former, the accumulations of sand, mud, and gravel may have been deposited; and by the latter, the blocks, however large, may have been detached and transported from their parent rocks to the distant regions they now occupy.* The general course of the drift and erratic boulders in the northern parts of Europe and America appears to have been from the north and north-west towards the south and south-east;† as if the materials had been brought by polar currents from the northern to the southern regions; hence the term "*northern drift*" is often employed to designate the alluvium and boulders which belong to this category.

Over vast regions of the north of Europe, in Poland, Russia, &c., erratic boulders, chiefly of crystalline and palæozoic rocks, are profusely scattered over the beds of alluvial debris, and upon the exposed surfaces of the older strata. In Sweden, these phenomena are strikingly displayed. The transported blocks occur in clusters, on mounds and ridges of sandy loam termed *osar*, sometimes at a height of from 200 to 300 feet above the adjacent plains. The origin of these widely spread erratic boulders is in the granitic and palæozoic rocks of Scandinavia. The travels and investigations of Sir R. Murchison have afforded a satisfactory solution of this problem. It appears that at a very remote period the granitic and ancient sedimentary rocks of Scandinavia were upheaved, and afterwards split and shattered to pieces by the expansive effect of ice; and the fragments and detritus that were carried into the sea by the action of

* The power of icebergs in transporting blocks and immense quantities of earthy materials is elucidated in Lyell's Principles of Geology, and Murchison's Silurian System; see also several memoirs in the American Journal of Science; and Sutherland's remarks, Geol. Journ. vol. ix. p. 305.

† This can be well seen in the map illustrative of Dr. Bigsby's paper on the Erratics of North America, Geol. Journ. vol. vii. p. 215, pl. 14. See also Lyell on the well-marked trains of erratic blocks in Massachusetts, Royal Institution Notices, part 5, p. 86.

glaciers and torrents were urged on by subaqueous currents, and large masses transported by ice-floes during the summer season, and deposited on the sea-bottom hundreds of miles to the southward. These submarine deposits, covered here and there by erratic boulders dropped by the melted icebergs, were subsequently elevated above the waters, and now constitute the vast plains of Russia and other parts of northern Europe; the transported blocks remaining as durable monuments of the physical changes which converted the ocean-bed into dry land.*

In England there are no tracts covered by boulders of such magnitude as to be comparable with the instances above adduced; but the same phenomena are observable on a smaller scale in various districts. Boulders of the granites, porphyries, syenites, and slaty rocks of the Cumberland mountains are dispersed northward and towards Carlisle, southward towards the bay of Morecombe, and eastward to the foot of the Pennine chain. They may be traced from Lancaster "at intervals through the comparatively low country of Preston and Manchester, lying between the sea and the Yorkshire and Derbyshire hills, to the valley of the Trent, the plains of Cheshire and Staffordshire, and the vale of the Severn, where they occur of considerable magnitude."† The quartz-rocks of the Lickey Hills, between Birmingham and Bromsgrove, in Worcestershire, have yielded immense beds of pebbles, which are thickly spread to the south and east, into the valleys of the Evenlode, Cherwell, and Thames, and through the gorge of the chalk-downs, as far as Read-

* See "Geology of Russia," for a full consideration of the "*Scandinavian Drift*," and the phenomena connected therewith.

† Professor John Phillips's "Treatise of Geology." One of the most remarkable occurrences of boulder-drifts in England is that described by Murchison as spread over a tract in Staffordshire, at Trysall and Trescott, and presenting enormous masses of transported granite.—*Silur. Syst.* p. 535

ing,* and even down the valley of the Thames as low as the neighbourhood of London.

In some of the examples quoted, the surface of the country is not unfavourable to the passage of such materials as compose the drift, if urged on by floods or sudden rushes of water; and, if it be assumed that the Cumberland mountains were of sufficient altitude during the boulder-period to accumulate glaciers, the torrents produced by the melting of the ice in the summer seasons would account for some of these beds of transport. But in many instances the physical configuration of the surface forbids this interpretation; and the subaqueous condition of the country, and the action of currents, waves of translation, and ice-floes, offer the most satisfactory explanation of the phenomena here presented to us, which have been regarded as presenting, on the whole, strong evidences in favour of the supposition of the existence of a very cold and "glacial" † climate in this north European area, at least, during the latest tertiary, or newer pliocene period."‡

17. PLIOCENE BEDS OF SICILY.—From the large proportion of recent species of shells which occur in the plio-

* See "A Description of the Quartz-Rock of the Lickey Hill in Worcestershire, and of the strata immediately surrounding it;" by the Rev. Dr. Buckland.—*Geol. Trans.* vol. v. p. 506.

† See E. Forbes's valuable memoir on the subject of the Glacial Epoch in the "Geol. Survey Memoirs," vol. i.

‡ Our limits will not admit of any further notice of the erratic blocks of England; but it may interest the reader to know that there is a very instructive example of the drift, in the immediate vicinity of London, at Muswell Hill, beyond Highgate, which is capped with an accumulation of pebbles, boulders, and fragments of rocks of all ages, from the chalk downwards. The collections of Mr. Wetherell and Mr. Toulmin Smith, of Highgate, contain characteristic fossils of the chalk, oolite, lias, mountain-limestone, &c., with blocks and pebbles of granite, gneiss, and other crystalline rocks, all obtained from Muswell Hill. Geol. Journ. vol. ix. p. 291.

cene strata, the beds have often the characters of a modern aggregate.

The hills immediately behind Palermo rise to an elevation of about 200 feet above the level of the Mediterranean, and are in a great measure composed of coarse limestone, made up of friable shells, which are frequently in an admirable state of preservation; in some examples preserving even their markings and natural polish. The elegant and picturesque manner in which they are occasionally grouped renders them objects of great beauty and interest. These fossils, with but very few exceptions, are of species still living in the adjacent sea; a proof, that, when the limestone was formed, the same condition of the basin of the Mediterranean existed as at present, and that it was comparatively uninfluenced by the elevation of that portion of its ancient bed which now forms the range of hills.

In other parts of Sicily, limestone, blue marl, beds of shelly calcareous breccia, and gypseous clay occur, intermingled with volcanic products. In the *Val di Noto* there is a remarkable assemblage of these deposits, which have been described by Sir C. Lyell.*

The rising grounds of the Val di Noto are separated from the cone of Etna, and the marine strata on which it rests, by the plain of Catania, which is elevated above the level of the sea, and watered by the Simeto. The traveller passing from Catania to Syracuse by way of Sortina and the valley of Pentalica, may observe many deep sections of these modern formations, rising into hills from to two thousand feet in height, and entirely composed of sedimentary strata, with recent shells; these are associated with volcanic rocks. The whole series of strata, exclusively of the volcanic products, is divisible into three principal gronps. 1. The *uppermost*, compact limestone in laminated strata, with recent shells; total thickness, from 700 to 800 feet. 2. Calcareous sandstone, with schistose limestone. 3. Laminated marls and blue clays.

The above groups contain shells and zoophytes of the same species as those from Palermo just noticed. The large

* Principles of Geology, Edit. 5th, vol. iii. p. 385.

scallop (*Pecten jacobæus*), which at the present day is profusely strewn on the Sicilian shores, is abundant, and beautifully preserved in the compact limestone; associated with immense numbers of very minute foraminifera, of species that now swarm in the waters of the Mediterranean. Leaves of plants and stems of reeds are of frequent occurrence.

The Apennines, which extend through the Italian peninsula, are flanked, both on the side of the Adriatic and the Mediterranean, by the Sub-Apennines, a low range composed of tertiary marls, sands, and conglomerates, some of which were contemporaneous with the Crag of England, while others belong to a more ancient epoch. These beds have resulted from the waste of the secondary rocks of the Apennines, which were dry land before these strata were deposited.

18. THE CRAG.—In England a very interesting assemblage of pliocene strata is spread over considerable areas, along the maritime parts of the eastern counties, Essex, Suffolk, and Norfolk,—and is provincially called the *Crag*. These beds extend along the coast forty or fifty miles, and form a tract which in some parts is ten or twelve miles in breadth (*see Plate* I.). The foundation-rock of that part of England is the white chalk, which is more or less covered by the London clay, on which the lower Crag is superimposed. The Crag strata consist of loam, clay, sand, and shelly gravel, containing beds of marine shells, sponges, and moss-corals (bryozoa), many of the layers being wholly made up of shelly and bryozoan detritus. In the upper part of the series there are intercalations of fluviatile deposits; and over all partial deposits of silt, containing mammalian remains, which insensibly blends with the superficial alluvium of the country.

Mr. Edward Charlesworth, to whom belongs the merit of having first accurately investigated and interpreted the zoological characters of the Crag, and of having pointed out the natural groups of this series, has established the following

subdivisions of the deposits that occupy the eastern coast of England:—

1. Insulated patches of lacustrine beds with mammalian remains. Above the whole of these deposits, is the usual alluvial accumulation and drift, in which are vast numbers of bones and teeth of Elephant, Bos, and other pachyderms, as well as of the big-horned Deer.
2. *Mammaliferous, fluvio-marine*, or *Norwich Crag*. Sandy loam and clay, more or less charged with shelly detritus; it occurs in certain localities at Southwold, Norwich, Cromer, &c. This is an extension of the Red Crag, and contains bones and teeth of several extinct mammalia, including a species of Mastodon, associated with those of existing and indigenous species.
3. *Upper* or *Red Crag*. So named from its deep ferruginous colour. It consists principally of quartzose sand, with comminuted and water-worn shells, moss-corals, bones and teeth of fishes, and numerous mammalian remains. These beds, when occurring in the same locality, are invariably superimposed on the Lower Crag. They attain a thickness of upwards of forty feet, and abound in marine shells, especially numerous species of *Murex*, *Buccinum*, and *Fusus;* among the latter is the *Fusus contrarius* (so named because the spiral convolutions pass from right to left, instead of in the opposite and ordinary direction), a well-known shell, formerly in great request among collectors.*
4. *Suffolk* or *lowermost Crag*.† A series of calcareous and marly strata, loose white sands, layers of shells, sponges, and bryozoa, and concretionary bands of stone. It abounds in shells, echinoderms, sponges, and moss-corals (especially of the genus *Fascicularia*), and these occur in so perfect a state as to indicate that they lived and died on the spot; for many of the sponges and bryozoa are in the upright position in which they grew. This group is upwards of twenty feet in thickness, and extends along the coast of Suffolk, over an area of twenty miles in length and three or four in breadth.

The Upper and Lower Crag have yielded to the researches of Mr. Searles Wood, and others, upwards of 400 species of

* See Parkinson's Organic Remains of a former World; vol. iii. pl. 6, fig. 5; Pictorial Atlas, pl. 57, fig. 5.

† As neither corals nor corallines are characteristic of this Crag, which on the contrary abounds with sponges and bryozoa, the name "Coralline," formerly applied to it, is evidently an objectionable misnomer.

shells, numerous sponges and moss-corals, teeth of several fishes of the Shark family, some of large size (*Carcharias megalodon*), teeth of Eagle-rays (*Miliobatis*), and ear-bones (petro-tympanic)* of Whales and other cetaceans. The bryozoa are of extinct genera; and the echinoderms,† of which there are nineteen species, are mostly distinct from any in the adjacent seas. Microscopic shells of foraminifera are abundant. Terebratulæ of great size are often met with; specimens six inches long have been obtained by Mr. Charlesworth.

The proportion of recent forms among the fossils of the two divisions of the Crag, the Upper, comprising the Red Crag and the Norwich Mammaliferous beds, and the Lower or bryozoiferous Crag, is not quite the same in the two cases;‡ although the difference is not great enough to allow of the separation of the two groups in geological time.

The recent forms of Gasteropoda predominate in the Upper Crag; and the recent forms of Bivalves are the most numerous in the Lower.

The Mammaliferous Crag has evidently originated in deposits of silt and sand brought down from adjacent land by a river or streams of fresh water into a creek or bay in which marine detritus was accumulating. With numerous marine shells, it contains some fluviatile and terrestrial species; and in it have been found teeth of the Mastodon, Ursus spelæus,§ and other contemporaneous fossil mammalia.

* Monograph of the Fossils of the Crag, Palæontographical Society, 1848—56.

† E. Forbes, Monog. of Tertiary Echinod. Pal. Soc. 1852.

‡ We learn from Mr. S. Wood's conchological investigations on the Crag Mollusca, lately given to the world in his highly valuable monograph, that, out of the 211 mollusca of the Lower Crag, 114 are also recent; and out of the 202 belonging to the Upper Crag, 122 are recent. Hence there is about $\frac{1}{19}$ more recent forms in the Upper than in the Lower, or very nearly ·064.

§ Mag. Nat. Hist. vol. iii. p. 450.

The uppermost beds appear to be entirely lacustrine or fluviatile, for they contain seed-vessels, remains of insects, fresh-water shells, and bones and teeth of land quadrupeds; comprising those of rat, mole, bear, boar, deer, ox, horse, hippopotamus, rhinoceros, elephant, and beaver, and the large extinct form of the latter, that occurs in the mammoth-drift of Russia (the *Trogontherium*, see p. 155).*

The passage of the mammaliferous crag into the superficial drift is in many places so imperceptible, that no line of chronological separation can be drawn; and our previous remarks on the deposits of the valley of the Thames render further comment unnecessary.

19. MIOCENE, OR MIDDLE TERTIARY.—The miocene are defined as strata containing but a small proportion of recent species of shells, seldom exceeding 20 or 30 per cent.; but there are exceptions to the rigid application of this rule in many of the strata comprised in the middle tertiary. Near Bordeaux, and in Piedmont, Hungary, and other parts of the continent, groups of miocene strata occur, and have been described by Lyell and other geologists.

20. EOCENE, OR LOWER TERTIARY DEPOSITS.—I now proceed to the consideration of the *Eocene*, or those strata which are of the highest antiquity among the tertiary deposits, and occupy basins or depressions of the chalk, where that formation constitutes the fundamental rock of the country. Every step of our progress will now be replete with increased interest, and the relics of new and extraordinary forms of being will appear before us. I shall pass rapidly over the stratigraphical character of these rocks, that our attention may be more fully directed to the organic remains which they enclose.

I will first describe the geographical distribution and ge-

* At Ostend, near Bacton, Norfolk. Professor Owen has figured and described the most important of these relics in his "British Fossil Mammalia."

neral characters of a few of the principal groups, and the more remarkable fossil animals and plants; and then survey those regions of central France, of the Rhine, and of South America, which have been the scenes of active volcanos during the tertiary epoch.

It may be regarded as a singular coincidence, that the capitals of Great Britain and France are located on strata of the same geological age. Paris is situated on a vast alternation of marine and fresh-water beds, lying in a depression of the chalk; the latter forming the boundary of the area in which the city is placed. London also is built on clays, sands, and pebble-beds, filling up a basin of cretaceous strata, the margin of which skirts the area of the ter-

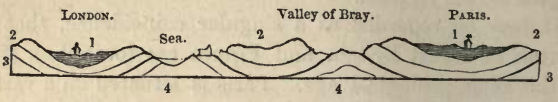
LIGN. 35.—TERTIARY BASINS OF PARIS, LONDON, AND HANTS.

(From Mr. Webster's Map; Geol. Trans. Vol. II.)

The shaded sites of London and Paris, and of part of Hants and the Isle of Wight, indicate the tertiary deposits.

tiary on the south, but leaves it open to the sea on the east. In Hampshire, and on the northern part of the Isle of

Wight, a series of contemporaneous marine beds, with interspersions of fresh-water deposits, in like manner rest upon the Chalk. The relative situation and comparative extent of these three basins are shown in the map (*Lign.* 35); and



LIGN. 36.—SECTION FROM HERTS, TO SENS, IN FRANCE.
(From Lyell's Elements of Geology.)
1, 1, Tertiary; 2, 2, Chalk; 3, 3, Greensand; 4, 4, Wealden.

the ideal section (*Lign.* 36), from Hertfordshire across the British Channel to Sens in France, explains the position of the London and Paris basins, and of the underlying chalk and wealden deposits.

21. THE PARIS BASIN.—The Paris basin is from east to west about 100 miles in extent, 180 from north-east to south-west; the greatest total thickness of the beds, or, in other terms, the depth passed through to reach the chalk, amounts to several hundred feet.

The strata, commencing with the uppermost, and descending to the most ancient, present the following characters:—

1. *Upper fresh-water marls*, with interstratified layers of flint or chert, containing seed-vessels of aquatic plants (*Charæ*, p. 86), and animal and vegetable remains. These beds are attributed to lakes and marshes, which existed after the marine sands (No. 2, below) had filled up the basin.
2. *Upper marine formation*, consisting of marls, micaceous and quartzose sand, with beds of sandstone abounding in marine shells.
3. *Gypseous marls and limestones;* with fluviatile shells and bones of terrestrial animals. These are supposed to have been discharged by a river which flowed into the gulf; the gypsum being precipitated from water holding sulphate of lime in solution, in the same manner as the travertine or calcareous tufa, of which we have already spoken (p. 73).
4. *Calcaire grossier; a*, Marls, limestones, and sandstones, containing terrestrial, fresh-water, and estuarine shells and plants, (35 feet); *b*, a coarse softish limestone, or calcareous freestone,

passing into calcareous sand, and abounding in marine shells (40 feet).—These beds often alternate, and are considered by M. Constant Prevost to be contemporaneous formations; the marine strata having been formed in those parts of the basin which were open to the sea, and the fresh-water limestone by mineral waters poured into the bay from the south; the continent being situated then, as now, to the south, and the ocean to the north. Layers of *miliolite limestone*,* almost entirely composed of the microscopic shells of foraminifera, occur in this part of the basin. *c.* Calcareous greensands, with flint-pebbles and marine shells (25 feet).

5. *Plastic clay and sand.* Strata of clay and sand, with fresh-water shells, drifted wood, lignite, leaves, and fruits; with bands of limestone containing marine shells.
6. *The lowermost.* Chalk-flints, broken and partially rolled, sometimes conglomerated into ferruginous breccia.

From this rapid sketch, we perceive that the strata which occupy the Paris basin have been produced by a succession of changes that readily admits of explanation by the principles enunciated in the previous lectures. Here we have an ancient gulf in the old chalk-region, which was open to the sea on one side, while on the other it was supplied by rivers charged with the spoils of the country through which they flowed, and carrying into the sea the remains of animals and plants, together with fresh-water shells; and there were occasional introductions of mineral waters. Changes in the relative level of the land and sea took place, and thus admitted of new accumulations upon the previous deposits; lastly, the country was elevated to its present altitude above the sea. Mutations of this kind, as we have already seen, are in progress at the present moment, and afford a satisfactory elucidation of these interesting phenomena. I reserve for the present any remarks on the fossils of the Paris basin, and pass to the examination of synchronous strata in our own Island.

22. The London basin.—The tertiary deposits on which

* So called from its enclosing immense quantities of a minute shell, named *Miliola*.

the metropolis of England is situated are spread over a considerable area, which is bounded on the south by the North Downs, and extends on the west beyond High-elm Hill, in Berkshire. It is flanked on the north-west by the chalk-hills of Wiltshire, Berkshire, Oxfordshire, Buckinghamshire, and Hertfordshire. On the east it is open to the sea; the Isle of Sheppey, situated in the mouth of the Thames, being an outlier of the same deposits.* These beds extend over Essex, a considerable part of Suffolk, Epping and Hainault forests, the whole of Middlesex, and a portion of Bucks. The tertiary deposits comprised in this series are subdivided as follows:—

1 *Bagshot Sands;*—sands, sandstones, foliated marls, and concretionary masses of siliceous sandstones, with a medial group of argillaceous beds.

2. *London Clay;*—a tenacious bluish-black clay, with layers of septaria, resting on a pebble-bed, which sometimes passes into a shelly conglomerate (*Basement-bed*).

(With the first division, Mr. Prestwich places the *Bracklesham sand and clay;* and with the latter the *Bognor* rocks.)

3. *Woolwich and Reading Beds;* †—mottled clays, sands and occasional sandstone, pebble-beds, and lignite.

4. *Thanet Sands;* ‡—nearly pure siliceous sands, with occasional concretions of sandstone.

The site of the metropolis and its environs is on the London clay, which abounds in marine remains, and constitutes

* See Mr. Webster's paper in the Geolog. Trans. vol. ii.; Conybeare and Phillips's Geology of England and Wales; also Mr. Prestwich's papers in the Journal of the Geological Society, and his Memoir on the water-bearing strata of London, a work in which this author's intimate knowledge of the district elucidates the general geology as well as the water-capabilities of the neighbourhood of the metropolis.

† Formerly known as the "Plastic clay;" but, as the Bagshot series, towards the west of England, supplies a great thickness of plastic clays, the name cannot be limited to the one series. See Quart. Journ. Geol. Soc. vol. x. p. 75.

‡ See Quart. Journ. Geol. Soc. vol. viii. p. 235.

the great mass of the materials that fill up this ancient gulf of the ocean. Immediately upon the chalk, however, there are thick beds of marine sands (Thanet sands), and above them mottled clays, called the Woolwich and Reading beds, (the *Argile plastique* of the Paris basin), in which fresh-water shells, plants, and drifted wood are found in some localities. The clay and gravel-pits at Woolwich, on the banks of the Thames, exhibit strata full of fresh-water univalve and bivalve shells; and at Plumstead, Bexley, and other places marine bivalves occur in clay and in indurated argillaceous limestone. The boulders and masses of sandstone which are abundant in some of the chalk-valleys, and on the flanks of the Downs, and are called *Grey-wethers*, *Sarsden-stone*, or *Druid-sandstone*, from being the principal material employed in the construction of Stonehenge and other Druidical monuments, have been derived chiefly from the Woolwich-Reading series, though some may have remained from the destruction of the lower Bagshot sands, and others from the basement-bed of the London Clay.* In some instances, layers of green sand lie upon the chalk, which at Reading contain immense quantities of oyster-shells: a similar accumulation of shells occurs near Norwood and at Headley in Surrey, a few miles from Reigate. At Bromley, in Kent, there is an extensive bed of oyster-shells with pebbles of chalk-flints interspersed, the whole being cemented together by a calcareous deposit into a remarkable shell-conglomerate, which is in much request for grottoes and ornamental rock-work.

The London Clay is found immediately beneath the gravel which so generally constitutes the subsoil of the metropolis; it is of great extent, and varies from 300 to 600 feet in thickness. The blue clay produces a dark, tough soil, with occasional intermixtures of green and ferruginous sands, and variegated clays. It abounds in layers of spheroidal nodules

* Prestwich, Quart. Journ. Geol. Soc. vol. x. p. 123

of indurated argillaceous limestone, internally traversed by veins of calcareous spar, that radiate irregularly from the centre to the circumference. From the appearance of septa or partitions which this character confers, these concretions are called *Septaria:* shells and other organic remains frequently form the nuclei of these nodules, which are extensively used in the manufacture of cement. Many other argillaceous strata contain concretionary spheroids of this kind: beautiful specimens are obtained from the Lias and the Oxford clay, and are cut and polished for tables and other articles. The septaria are commonly disposed in horizontal lines, and lie at unequal distances from each other. Brilliant sulphide of iron abounds in the clay, and permeates the septaria and many of the organic remains. Crystallized sulphate of lime, or selenite, is also common in these and other argillaceous strata. The cuttings through Highgate Hill, to form the archway,—the excavations in the Regent's Park,—the tunnels carried through a part of the same ridge of clay at Primrose Hill, in the line of the Birmingham Railroad,—the cuttings of the Great Northern, the South-western, and other railways,—and the explorations by wells over the whole area around London, have brought to light such prodigious quantities of organic remains, that the fossils of this deposit are almost universally known. The late Mr. Sowerby long since called attention to these productions, the first plate in his *Mineral Conchology* being devoted to the nautili of the Highgate clay. Immense numbers of marine shells of extinct species; crabs, lobsters, and other crustaceans; teeth of sharks, and of many other genera of fishes; bones of crocodiles, turtles, serpents, and birds; leaves, fruits, stems of plants, and rolled trunks of trees perforated by boring shells,—occur throughout these strata, but are located in greater abundance in some spots than in others.*

* Messrs. Wetherell and Edwards have fine collections of the Highgate fossils. See Prestwich, Quart. Geol. Journ. vol. x. p. 401.

23. The Isle of Sheppey.—The Isle of Sheppey is entirely composed of the London clay; and the thickness of the beds is upwards of 550 feet. It has long been celebrated for its organic remains; and I may observe, that the discovery of seed-vessels and stems of plants in pyritous clay, in a visit which I made to Queenborough, when a youth, tended to confirm my early taste for geological researches. The cliffs on the north of the island are about 200 feet high, and consist of clay abounding in *septaria*, which are washed out of the cliffs by the action of the sea, and collected for cement. The organic remains are, however, unfortunately so strongly impregnated with pyrites, that the collector often finds the choicest fossil fruits in his cabinet, like the fabled apples of the Dead Sea, one day perfect and brilliant, and the next decomposed and fallen to pieces, leaving only an efflorescent sulphate of iron. A solution of isinglass in spirits of wine, applied as a varnish, is one of the best preservatives. The same species of animal and vegetable remains that are found in the blue clay of the metropolis are also met with in profusion in the Isle of Sheppey.*

Fruits, seed-vessels, with stems and branches of trees of a tropical character, probably drifted by currents into the gulf in which the London clay was deposited, occur in such abundance and variety in the Isle of Sheppey, that the existence of a group of spice-islands at no great distance seems necessary to account for so vast an accumulation of vegetable productions. The seed-vessels are referable to several hundred species; some are related to the Cardamom, Date, Areca, Cocoa, Cotton-plant, Bean, Cucumber, Acacia, Pepper, &c.† The wood found in the Sheppey clay is generally in the state of a pyritous lignite, with the ligneous fibres and circles

* See Medals of Creation, vol. i. p. 175.

† See Figures and Descriptions of the Fossil Fruits of the London Clay, by J. S. Bowerbank, Esq. F.R.S.; and in Medals of Creation, vol. i. p. 188.

of growth well defined; it is often veined with brilliant pyrites, and the fissures and cavities are frequently filled with that mineral. It is rarely that any considerable mass of this wood is found free from the ravages of a species of teredo,* resembling the recent *Teredo navalis*, or *borer*, which inhabits the West Indian and other seas. The shelly tubes sometimes remain, but their cavities, as well as the perforations in the wood, are more or less filled up with pyrites, indurated clay, argillaceous limestone, or calcareous spar; and specimens, when cut and polished, exhibit interesting sections of these meandering channels. The structure of the wood is generally well preserved.†

24. BAGSHOT SANDS AND CLAYS. — At Highgate and Hampstead, Purbright and Frimley Heaths, in Surrey, and on Bagshot Heath, extensive beds of siliceous sands, with a middle group of clays and marls, occur, but they contain very few traces of organic remains; the fossils hitherto observed are principally casts of shells of Bracklesham species. In cutting through the summit of Goldsworth Hill, four miles north of Guildford, on the line of the London and Southampton Railway, teeth and other remains of several genera of fishes were discovered; the teeth of sharks, and the palates of rays, were the most numerous. Teeth of the saw-fish (*Pristis*), and of several new genera of cartilaginous fishes, were also collected.‡

In many of the wastes and unproductive heaths around London, the arenaceous deposits of this group form the subsoil; and they constitute that picturesque spot, Hampstead Heath, and cap Highgate Hill and the adjacent heights. The beds of shingle associated with these sands, with the

* Medals of Creation, vol. i. p. 193, *Lign.* 63.

† For a particular account of the Island and its fossils, see "*Excursion to the Isle of Sheppey*," in Medals of Creation, vol. ii. p. 838.

‡ See Proc. Geol. Soc. vol. ii. p. 687. Quart. Geol. Journ. vol. iii. p. 378. Geology of the Isle of Wight, p. 59.

base of the London clay, and with the Woolwich beds, have unquestionably been derived from the ruins of the chalk-formation.*

25. NATURE OF SPRINGS.—From the alternation of sands and other porous strata with stiff impervious clays, throughout the London basin, the metropolitan district is favourable for obtaining water by means of the borings termed Artesian wells, by which means perennial fountains are made to rise from the natural reservoirs in the lowermost beds of sand, and in the chalk. The nature of these wells is easily explained. The descent of moisture from the atmosphere upon the earth, and its escape into the basin of the ocean by the agency of streams and rivers, were noticed in the first lecture. The rain, falling on a gravelly or porous soil, descends through it, until its progress is arrested by a clayey or impervious stratum, which thus forms a natural tank that receives the water, and a subterranean reservoir or pool will be the result, according to the direction and configuration of the overlying bed of clay. This state of things will continue, until, by an increased supply, the water rises above the level of the basin or channel, and either overflows, or escapes through fissures in the rocks, to another level. If the course of the waters be subterranean, the beds of slightly coherent stone are worn away, and chasms or caverns are formed; hence the underground rivers and streams, of great

* Mr. Prestwich, whose indefatigable and able researches have largely contributed to establish correct views of the natural groups of which the British, French, and Belgian tertiaries consist, regards the Bagshot sands as a triple series; arenaceous strata constituting the upper and lower, and argillaceous beds the middle division: to this series he refers the sands and clays of Bracklesham, and the Calcaire grossier, with the underlying sands and shelly beds, of France. The geological character of the eocene series of the London and Hampshire districts is that of an extensive marine formation (part of the great Nummulitic series), with intercalations of fluviatile deposits in the lower (or Woolwich) group, and passing into an estuarine and fresh-water condition in the upper (Isle of Wight, fluvio-marine series).

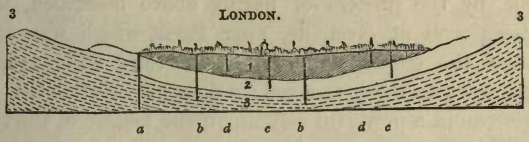
extent, which occur in many places (p. 56); but, if the water find its way to the surface, a spring bursts forth. This is the nature of all springs, except those which arise from very great depths, such for example as the thermal waters of many countries; these probably originate from the condensation of steam, evolved through fissures by volcanic agency. Streams impregnated with the mineral substances contained in the strata through which they flow are called mineral waters. Those in the tertiary strata near Epsom contain sulphate of magnesia, whence the name of Epsom salt, given to this substance wherever it occurs.*

26. ARTESIAN WELLS.—But pervious strata frequently alternate with others which are not so; and they, likewise, form basins, the areas of which are partially filled with clay, through which water cannot pass: in such a case it is obvious, that the sands beneath the clay, fed by the rain which descends on the uncovered margin of the basin, must constitute a reservoir, and the water gradually accumulate beneath the central plateau of clay, whence it cannot escape. If this bed of clay be perforated, either by natural or artificial means, the water must necessarily rise to the surface, and may be thrown up in a jet to a considerable height, which will depend on the level of the fluid in the subterranean reservoir; such is the phenomenon observable in the Artesian wells in and around London. Argillaceous strata are generally found to be dry within, and the blue clay confines the water contained in the sands beneath; the engineer therefore perforates the clay, introduces tubes, and taps the natural tank, and the imprisoned waters rush to the surface; by this method perennial fountains have been formed at Tooting, Hammersmith, Fulham, &c.†

* See notes on the Geology of Surrey, in Brayley's History of that county.

† Consult Dr. Buckland's Bridgewater Essay, p. 561; and Mr. Prestwich's admirable work on the Water-bearing Strata of London.

The wells sunk into the London clay (*Lign.* 37, 1, *d*, *d*,) do not yield pure water; but the sandy strata alternating with



LIGN. 37.—PLAN OF THE ARTESIAN WELLS NEAR LONDON.

1. The London clay. 2. The Woolwich clays and Thanet sands. 3. The chalk.

a, *b*, *b*, Borings that reach the chalk. *c*, *c*, Wells in the plastic or Woolwich clay and sands. *d*, *d*, Wells in the London clay.

the clays afford a supply, the quantity and quality of which depend on the nature of the rock. The borings which reach the sands beneath the plastic clay (*Lign.* 37, 2, *c*, *c*) furnish good soft-water; but the wells that extend to the chalk (*Lign.* 37, 3, *a*, *b*, *b*) obtain the most copious springs, the water often rising to the surface in a perennial fountain.*

The wells in London vary in depth from 100 to 600 feet; but the total thickness of the clay in some places is estimated

* As the white chalk, into which the Artesian borings in London are generally carried some twenty or thirty feet, is not a retentive rock, but on the contrary is so porous that not a natural pool or lake is to be found throughout the chalk-districts, except under some peculiar local conditions, a few words must be added, to explain this anomaly. The *chalk-marl*, which is the first retentive bed of any considerable extent in the cretaceous formation, lies at a depth of many hundred feet beneath the bottom of the London basin, and therefore could not, in ordinary conditions, form a reservoir that could be reached by artificial means, if the strata were either horizontal, or lying inclined in a direction from the central plateau of London; but the surface of the chalk forms a deep trough, in which the London clay is situated, and thus the drainage from the surrounding chalk-hills flows into the centre of the basin, and furnishes an almost inexhaustible reservoir. I need not add, that attempts to obtain water by Artesian borings in any chalk-district, where the strata are horizontal or inclined, will fail, unless the beds immediately upon the *chalk-marl* could be reached. The borings for water near Southampton exemplify these remarks. See the *Geology of the Isle of Wight*, p. 61.

at nearly a thousand feet. The most remarkable instance of success in obtaining a perennial fountain from a deep source, by the process of boring above described, is the Artesian well at Grenelle, near Paris, which was carried through the entire series of the tertiary and cretaceous strata, down to the greensand; a depth of 1800 feet! The water rose in a powerful column to the height of thirty feet above the highest part of Paris, and had a temperature of 91° Fahrenheit, being sufficiently hot for warming greenhouses, &c. See Appendix G.

27. THE HAMPSHIRE BASIN.—The upper series in the London basin does not present an alternation of marine and fresh-water deposits, like that of Paris; but in Hampshire and the Isle of Wight, there is an extensive suite of upper eocene tertiary beds, composed of fresh-water clays, sands, and limestones, associated with marine and estuarine strata. On the east, a small outlier of the lower beds of the Woolwich series appears at Castle Hill, near Newhaven, in Sussex;* and to the west of Brighton, the London clay rises to the surface, and forms the subsoil between the Downs and the sea-shore. The inland boundary of these tertiary strata stretches by Chichester, Emsworth, and Southampton, to Dorchester; and the tertiary clays and sands are spread over the whole area of the New Forest and the Trough of Poole, being flanked by the chalk on the north, north-east, and north-west, and open to the sea on the south. The Isle of Wight, though now separated from the mainland, is a disrupted mass of the formations of the south-east of England; the chalk-basin having been broken up, and the cretaceous strata, with the superimposed sands and clays, thrown along a certain line into a vertical position. This phenomenon is strikingly displayed at the north-west extremity of the island, at Alum Bay, and in the eastern, at Culver Cliff and Whitecliff Bay.

* Geology of the South-East of England, p. 53.

28. ALUM BAY.*—Alum Bay, so called from the alum formerly extracted from the decomposing pyrites with which

LIGN. 38.—ALUM BAY, ISLE OF WIGHT; FROM THE WEST.
a, Chalk strata, nearly vertical. *b*, *b*, Vertical Tertiary strata.

the clay abounds, is well known to the visitors of the Isle of Wight. This sketch (*Lign.* 38) presents a general outline of the bay; *a* indicates the vertical chalk; *b*, *b*, the tertiary strata, consisting of sands and clays of an infinite variety of colour, including green, yellow, red, crimson, rusty, white, black, and brown. The appearance of these cliffs is well described by Mr. Webster, whose memoir on the strata above the English Chalk † formed a new era in British Geology, and raised our tertiary series to an importance equal to that of the Paris basin.

* For the details of the section afforded by the cliffs of Alum Bay, the student will have to refer to Mr. Prestwich's Memoir and plate in the Journal of the Geological Society, vol. ii.; and especially to the lately published part of the Memoirs of the Geological Survey, in which the fluvio-marine series is fully treated of by Prof. E. Forbes, and where both these beds and the marine tertiary deposits are enumerated by Mr. Bristowe.

† Geol. Transact. vol. ii. p. 161.

"The clay and sand cliffs of Alum Bay," he says, "afford one of the most interesting natural sections that can well be imagined. They exhibit the actual state of the strata immediately over the chalk, before any change took place in the position of the latter. For, although the beds of which they are composed are quite vertical, yet, from the nature and variety of their composition, from the great regularity and numerous alternations of the layers, no one who has viewed them with attention can doubt that they have suffered no change except that of having been moved, with the chalk, from a horizontal to a vertical position."

29. LOWER TERTIARY STRATA OF THE HAMPSHIRE BASIN.—The London clay extends throughout a great portion of the area of the Hampshire basin, its peculiar fossils abounding in many localities. Castle Hill, near Newhaven, which has been already mentioned as an isolated portion of the Woolwich series, is made up of sands, marls, and clays, with beds of oyster-shells and shingle; these deposits form the upper part of the hill, and rest upon the chalk of which the lowermost fifty feet of the cliff are composed.* The *subsulphate of alumina* (Websterite),† a rare mineral, occurs in the ochraceous clay which is in immediate contact with the chalk. Selenite, or crystallized gypsum, abounds in the marls; and there is a layer of lignite, a few inches thick, containing impressions of dicotyledonous plants.‡ The clays abound in marine and fresh-water shells; some of the layers being aggregations of compressed shells, held together by argillaceous earth.§ The oyster-bed, where pebbles enter into the composition of the concreted masses, closely resembles the Bromley conglomerate (p. 231). I have collected a few teeth of sharks, and a series of eight vertebræ and a dorsal ray of a fish, some fifteen or twenty feet long, from the ironstone abounding in cyclades and other shells; this

* See Geology of the South Downs, p. 261.

† British Mineralogy, Tab. 499.

‡ Fossils of the South Downs, Pl. viii. figs. 1, 2, 3, 4.

§ Two species of *Potamides*, and one of *Cyclas* (both fresh-water genera), are the prevailing forms.

fish is evidently a species of *Ptychodus*, a genus hitherto only known in the Chalk. At Chimting Castle, near Seaford, on the eastern escarpment of the valley of the Ouse, olive-green sand and a ferruginous conglomerate of chalk-flints lie upon the chalk; proving the further eastward extension of the tertiary beds along the Sussex coast.*

The chalybeate hill, at Hove, in the western part of Brighton, consists of an outlier of the Woolwich beds; and proceeding towards Worthing, the London clay is perceived emerging from beneath the drift, which contains the remains of elephants and other mammalia. On the Bognor coast, an arenaceous limestone, full of the usual shells of the London clay,† constitutes a group of low rocks which in another century will probably have entirely disappeared. The beauty and variety of the fossil shells, particularly of the nautili, and of the fossil wood perforated by teredines, render them objects of considerable attraction to the amateur collectors, who visit that favourite watering-place.

In the blue clay at Bracklesham Bay, on the western coast of Sussex, fossil shells may be obtained at low water in profusion;‡ and this locality has afforded many remains of fishes and reptiles of great interest, and which are figured and described in the work of the late Frederick Dixon, Esq.§

* Geology of the South-east of England, p. 62.

† Fossils of the South Downs, p. 271.

‡ Bracklesham Bay, on the western coast of Sussex, is bounded by a low cliff composed of blue clay and green sand, full of fossil shells, fishes' teeth, and other remains. For a particular account of this productive tertiary locality, see "*Excursion to Bracklesham Bay*," in the Medals of Creation, vol. ii. p. 844. For notes on the Geology of the coasts of Sussex and Hampshire, and for full descriptions and satisfactory figures of the Tertiary (and Chalk) fossils of that district, the student must consult Dixon's beautiful work, 4to, Bohn, London.

§ These fossils are now in the British Museum, Mr. Dixon's collection having been purchased by the trustees, after his death, for the sum of £500.

Hordwell and Barton Cliffs, in Hampshire,* have long been celebrated for similar fossils; and shells from these localities are to be found in almost every collection of organic remains; but these strata have yielded to the recent researches of the Marchioness of Hastings, Mr. Searles Wood, Mr. P. Falconer, and others, relics of much higher import; namely, several new genera of mammalia, and species of Crocodilian, Ophidian, and Chelonian reptiles.

30. FRESH-WATER TERTIARY STRATA OF THE ISLE OF WIGHT.—The peculiarity of the eocene strata of the Isle of Wight, as compared with those of London, consists in the lacustrine and fluviatile character of the upper series of deposits, which are superimposed on marine strata identical with those of Barton and Bracklesham. These fresh-water and estuarine beds consist of marls, sands, and limestones, containing abundance of river and lacustrine shells, and a few mammalian bones and teeth belonging to some of the extinct Anoplotherioid genera found also in the Paris basin. This

LIGN. 39.—SECTION OF HEADON HILL AND ALUM BAY.

8. Gravel and sand, capping Headon Hill.
Bembridge limestone (freshwater, with many land-shells).
Osborne beds (fresh-water).
Upper (fresh-water)
Middle (marine)
Lower (fresh-water)
} Headon beds.

7. Headon Hill or Barton Sands'
6. Barton clay and sandy beds,
5. Upper and lower Bracklesham
4. and Bagshot sands and clays,
} Marine
3. London clay: Bognor beds,
2. Mottled clays, with sandy beds against the chalk: Woolwich series (fresh-water).
1. Chalk with flints; nearly vertical.

series is spread over the northern districts of the Island, forming the coast-line from Whitecliff Bay to Headon Hill

* These cliffs are described in the Geology of the Isle of Wight, p. 121. Mr. F. Edwards' Monograph of the Eocene Mollusca of England (Palæontographical Society) is the only work that comprises all the fossil shells of the London and Hampshire Tertiaries.

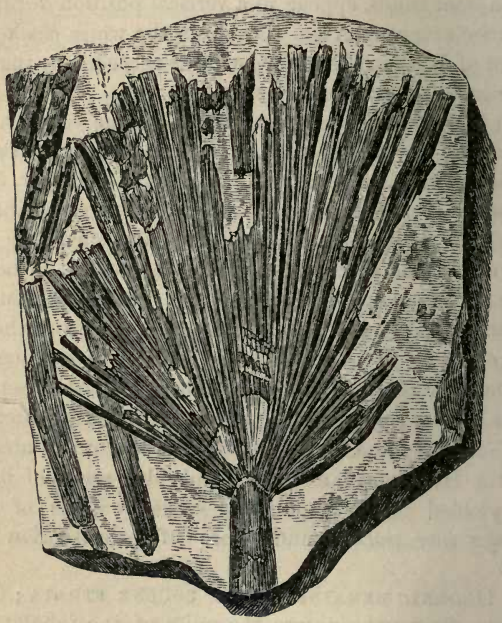
in Alum Bay. The relative position of the fluviatile and marine eocene strata is shown in *Lign.* 39: strata, the equivalents of the Bognor rocks, London clay, Bracklesham clay, and Bagshot sands, appear in a vertical position throughout the entire extent of Alum Bay, from the white chalk (1), to the foot of Headon Hill (7); and are succeeded by the mixed fresh-water and marine deposits (8).

Still higher members of the fluvio-marine series were recognised by the late Prof. E. Forbes at Whitecliff Bay and Hempstead Cliff. These are, 1. (highest) the Upper, Middle, and Lower Hempstead beds (fresh-water and estuarine alternating); 2. the Upper and Lower Bembridge Marls (fresh-water above, and chiefly estuarine lower down). The Bembridge limestone underlies these marls; and is best studied at Foreland Point and Whitecliff Bay, where it forms the rocky reef known as Bembridge Ledge. It is quarried here, also at Binstead, near Ryde, and at Calbourne and Shalfleet. The several beds of this limestone abound with fresh-water shells (see *Lign.* 41); and land-shells are found equally abundant. Both the Hempstead and the Bembridge series of deposits have yielded fossil plants and seeds, remains of turtles (*Trionyx incrassatus*), and bones of palæotherian mammals.*

31. ORGANIC REMAINS OF THE EOCENE STRATA; FOSSIL PLANTS.—So numerous are the relics of the inhabitants of the ancient lands and waters entombed in the strata we have thus cursorily surveyed, that I can only offer a very brief account of the organic remains. I will select a few of the fossils of the Paris basin as typical of the zoology of the

* These strata, and the most interesting fossils hitherto discovered in the Isle of Wight, are described and illustrated in the "Excursions round the Isle of Wight, &c." 3rd Ed. 1854. See also the Memoirs of the Geological Survey, 1856, for the important memoir (chiefly by the late Prof. E. Forbes) on the Fluvio-marine Upper Eocene deposits of the Isle of Wight, copiously illustrated with maps, sections, and plates.

older tertiary epoch, and notice such others from British localities as may be requisite for the elucidation of the subject.



LIGN. 40.—FOSSIL PALM-LEAF FROM THE BEMBRIDGE LIMESTONE, ISLE OF WIGHT

Dicotyledonous wood occurs in considerable abundance, in the state of large trunks and branches, which appear to have been drifted far out to sea, and are full of perforations enclosing shells of boring mollusca. The strata around London and in the Isle of Sheppey abound in specimens of this kind. Leaves and stems of palms have been found in the Paris basin, in the Isle of Wight, and in Dorsetshire; and the trunk of a tree related to the palm, nearly four feet in

diameter, at Soissons. Fruits belonging to trees allied to the pine, fir, areca, cocoa-tree, &c. have been discovered in several localities. The abundance of fruits, of numerous genera, belonging to hot climates, that are accumulated in the Isle of Sheppey * has already been mentioned (p. 233). Beds of lignite or *brown-coal* occur at Woolwich in Kent, Corfe in Dorset, Bovey Tracey in Devonshire,† and in various parts of France, the Netherlands, Germany, &c.

32. AMBER.—The beautiful substance so remarkable for its electric properties, Amber, is a production of the tertiary epoch, and is highly interesting in a geological point of view, from its containing insects and other organic bodies. The Amber in common use is chiefly obtained from submarine beds of lignite in Prussia, and along the coast of the Baltic; this substance being washed up by the action of the sea, and drifted on the shore. It is a fossil resin, the product of an extinct species of pine (*Pinus succinifer*). Insects, spiders, small crustaceans, leaves, and fragments of vegetable tissue are imbedded in some of the masses. Upwards of 800 species of insects have been observed; most of them belong to species and even genera that appear to be distinct from any now known; but others are nearly related to indigenous species, and some are identical with existing forms, that inhabit more southern climes.

The forests of Amber-pines (*Pinites succinifer*) were in the south-eastern part of what is now the bed of the Baltic,

* As the seed-vessels and other vegetable remains in the Isle of Sheppey are all of a tropical character, while those found in the eocene strata of Alum Bay, Hordwell, Bournemouth, and Newhaven are apparently of a temperate climate, as Nerium, Platanus, &c., Prof. E. Forbes infers that the former were transported from distant lands by oceanic currents, and that the latter belong to the indigenous flora of the countries inhabited by the Palæotheria and associated mammalia. See also Dr. Hooker's note on the Plant-remains from Reading, Journ. Geol. Soc. vol. x. p. 163. This question is still open for further elucidation.

† See Medals of Creation, vol. i. p. 72. Geol. Journ. vol. xii. p. 354.

in about 55° north latitude, and 37°—38° east longitude. The different colours of amber are derived from local chemical admixture. From the fragments of vegetable matter frequently contained in the amber, it has been ascertained that the amber-pine forests contained eight other species of Coniferous trees (*Abietineæ*), and several Cypresses, Yews, and Junipers, with Oaks, Poplars, Beeches, &c.; altogether ninety-eight recognizable species of trees and shrubs; constituting a flora somewhat of a North American character. There are also some ferns, and numerous mosses, fungi, and liver-worts.*

33. ZOOPHYTES. — Polyparia, or corals, and other zoophytes abound in some of the marine strata; but the species are not very numerous in the British series. Several kinds of flabellum, turbinolia, oculina, and other corals, are figured and described by authors.† The modern tertiary deposits (those of Palermo for example) abound in various kinds of flustræ and sponges. The bryozoiferous strata of the Crag are almost wholly made up of a few forms of *Tubuliporidæ* (p. 224).

The elegant little *Litharœa Websteri* was found at Bracklesham in Sussex by Mr. Bowerbank. Some of the tertiary strata of North America abound in corals.‡

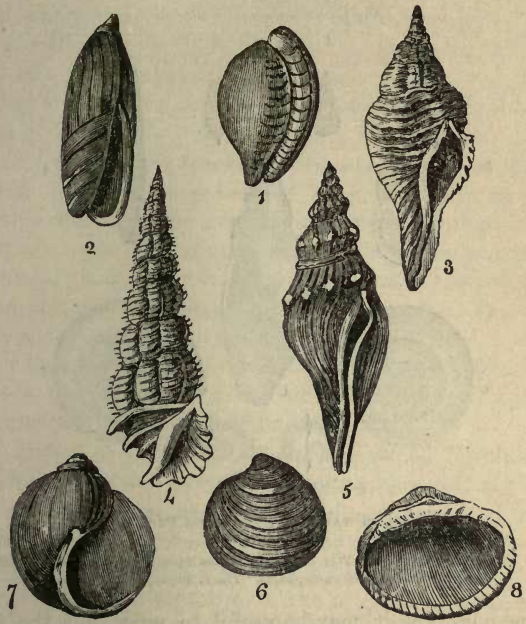
34. SHELLS OF THE TERTIARY STRATA. — The shells of the tertiary epoch already determined by naturalists amount to nearly three thousand. We have seen that some of the strata are almost entirely composed of these remains in a broken and compressed state, and many seams in the argillaceous beds consist of shell-dust. In some localities the

* Professor Göppert, Quart. Geol. Journ. vol. x. part 2, p. 1.

† See the highly illustrated Monograph on British Fossil Corals, by MM. Milne Edwards and J. Haime (Palæont. Soc.).

‡ Quart. Geol. Journal, vol. i. p. 495; Report on the Corals and Bryozoa from the Eocene and Miocene strata of North America, by Mr. Lonsdale.

shells are finely preserved; and the calcaire grossier at Grignon and Damery, a few leagues from Paris, has long



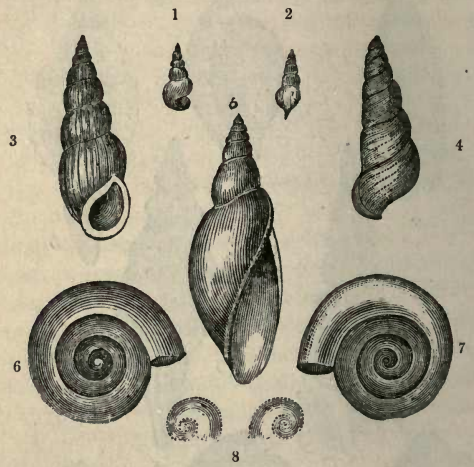
LIGN. 41.—MARINE EOCENE SHELLS OF THE PARIS TERTIARIES.

Fig. 1. Cypræa inflata. 2. Ancilla canalifera. 3. Fusus uniplicatus. 4. Cerithium lamellosum. 5. Pleurotoma dentata. 6. Lucina sulcata. 7. Ampullaria sigaretina. 8. Pectunculus angusti-costatus.

been celebrated for its beautiful fossils; hundreds of eocene species have been collected from one small area. Many of the species also abound in the London and Hampshire basins, as at Highgate, the Isle of Sheppey, Hordwell, Barton, Alum Bay, and Whitecliff Bay; and at Bognor and Bracklesham, on the Sussex coast.

I have selected a few specimens to convey an idea of their

usual characters and appearance (*Lign.* 41). Although, in mentioning the names of these shells, I do not expect that any but the scientific inquirer will endeavour to fix them on



[4] LIGN. 42.—FRESH-WATER SHELLS OF THE PARIS TERTIARIES.

Fig. 1, 2. Bulimus conicus. Figs. 3, 4. Cyclostoma mumia. Fig. 5. Limnæa effilea. Figs. 6, 7. Planorbis euomphalus. Fig. 8. Planorbis cylindricus.

the memory, yet it may be useful to point out the forms which prevail in these tertiary beds; for, as particular fossils are confined to certain strata, the experienced observer can often, at a glance, determine the relative antiquity of a deposit by an examination of a few species of shells. The whole of these forms must be familiar to you, as they belong to genera which swarm in our present seas. The *Cypræa*, or Cowry (*Lign.* 41, *fig.* 1), and the *Ancilla*, or Olive (*fig.* 2), are well-known types. The *Cerithium* (*fig.* 4) belongs to a genus most abundant in the sands of the Paris basin, and is remarkable for the elegance and variety of the

fossil species, which exceed by four times in number their living analogues. The *Cerithium giganteum* attains a considerable magnitude. Some masses of the Bognor rock are almost wholly composed of a species of *Pectunculus* (*fig.* 8). The *Ampullaria* (*fig.* 7) is abundant at Grignon, and commonly in a beautiful state of freshness.

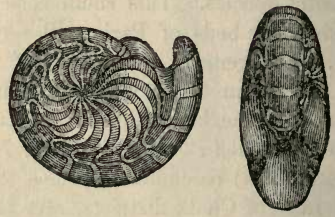
It has already been observed, that the shells of fresh-water mollusca possess characters by which they may be distinguished from marine species. This small selection (*Lign.* 42) from the fresh-water beds of Paris will serve to illustrate this remark. The general appearance of these shells will remind you of certain kinds which inhabit our ponds and rivers; particularly the large thin snail (*Limnæa*,* *fig.* 5), and the discoidal shell (*Planorbis*, *figs.* 6, 7, 8); while *figs.* 3 and 4 (*Cyclostoma*) resemble a species that inhabits the dry land, generally of Chalk districts. At Headon Hill, Binstead, Calbourne, &c. in the Isle of Wight, the clays and limestones are full of fresh-water shells.†

35. FOSSIL NAUTILUS.—Several species of Nautilus are found in the tertiary strata at Highgate, Sheppey, and Bognor; those enclosed in the septaria, or indurated argillaceous nodules, of the London clay possess considerable beauty, and admit of being cut into sections, which admirably display the internal structure of the original. I shall defer an explanation of the mechanism of these shells to the subsequent lecture, when other genera of the same order will come under our notice. The large splendid species *Nautilus imperialis*, of which hundreds of specimens have been collected from the cuttings at Highgate Tunnel and the

* The *Limnæa* and *Planorbis* are generally joint inhabitants of our pools and streams. They are pulmoniferous, that is, possess air-breathing organs; hence they are obliged frequently to rise to the surface of the water to respire the air.—See Plate I. of the *Geology of the Isle of Wight.*

† See Mr. F. Edwards' Monogr. Eocene Mollusca, Palæont. Soc.; and Memoirs Geol. Survey, 1856.

recent railway excavations, is figured in Mr. F. Edwards' Monograph above referred to, and in Sowerby's Mineral Conchology; a work which contains coloured representations of a great number of the British tertiary shells. I will only particularize a rare and elegant species, discovered by Mr. Wetherell, of Highgate, which is here figured of the natural size.



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LIGN. 43.—NAUTILUS (ATURIA) ZICZAC, FROM THE LONDON CLAY, PRIMROSE HILL.
(In the cabinet of Mr. Wetherell.)
Fig. 1. Side view. Fig. 2. Front view.

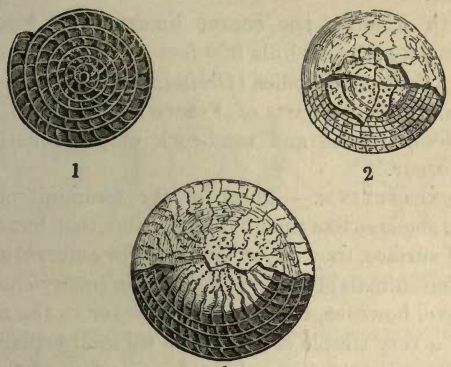
This shell is remarkable for the peculiar character of the *septa* or divisions, as expressed in the specific name; the siphunculus extends along the inner margin. The septa are distinctly seen in consequence of the external layer of the shell having been destroyed by decomposition.

36. NUMMULITES: AND OTHER FORAMINIFERA. — The fossils called *Nummulites* (from their resemblance to a coin) belong to those extremely minute forms of animals which are termed *Foraminifera*,* from the septa of the shells of many of the genera being perforated all over with openings or foramina.

The Nummulite, which is the largest of this order, is of a lenticular, discoidal form, and varies in size from a mere point to an inch and a half in diameter. The outer surface

* Pictorial Atlas of Organic Remains, p. 142, 186, plates 61 and 62.

is generally smooth, and marked with fine undulating lines. On splitting the shell transversely, it is found to consist of several coils, which are divided into a great many cells or chambers by oblique partitions (*Lign.* 44, *fig.* 1). The specimens figured in *Lign.* 44 are from the limestone which constitutes



LIGN. 44.—NUMMULITES, FROM THE GREAT PYRAMID OF EGYPT.

Fig. 1. Horizontal section of a Nummulite. Figs. 2, 3. Nummulites, with the external plates partially removed.

the foundation-rock of the Great Pyramid of Egypt, and of which that structure is in great part composed. Strabo alludes to the nummulites of the Pyramids, under the supposition that they are lentils which had been scattered about by the workmen, and had become converted into stone. This polished pebble from Egypt is a silicified mass of nummulites, the markings on the surface being sections of the enclosed shells.

The nummulites * are widely diffused through some of the ancient tertiary deposits, and form entire chains of calcareous hills. They constitute immense beds in the Alps

* See D'Archiac and Haime's beautiful Monograph on Nummulites in their "Anim. foss. de l'Inde." 1853.

and Pyrenees,* and are not confined to Western Europe, but occur also in Greece, Bulgaria, Southern Russia, Asia Minor, Persia, and in the west and east of Northern India. The sand and clay at Bracklesham and Stubbington, and certain of the beds in Alum and Whitecliff Bays, abound in nummulites.

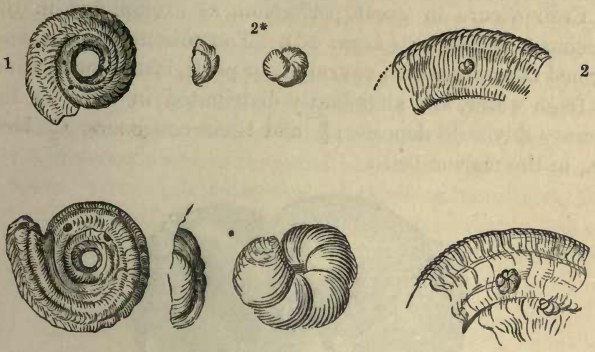
In North America, the eocene limestone of Suggsville, which forms a range of hills 300 feet in height, is entirely composed of lenticular bodies (*Orbitoides Mantelli*) related to this genus. In some parts of France and Belgium, beds of nummulitic limestone and sand-rock of great extent and thickness occur.

37. TRUNCATULINÆ. — Many of the foraminifera† have chambered shells so like that of the Nautilus, that, but for their perforated surface, they might be taken for embryotic cephalopoda. The animals of these polythalamia (many-chambered shells) have, however, no relation whatever to the nautilus, but are of a very simple structure, as we shall explain in the next lecture, when treating of the foraminifera of the chalk. These animalcules swarm in many of the tertiary strata; in the annexed sketch (*Lign.* 45) are shown two specimens of Truncatulinæ, adhering to a very characteristic shell (*Vermicularia*) of the London clay and the Bognor sandstone. The marine sands of the Paris basin are, in some localities,

* The Nummulitic rocks were not long since believed to occur in the cretaceous or upper secondary formations, as well as in the tertiary. The researches of Sir R. Murchison have set this long-agitated point at rest; for, by his labours in the Alps, Apennines, and Carpathians, he has shown that in no region of Europe is a true nummulite found beneath the base of the Lower Tertiary or Eocene. By comparing collections of fossils from Egypt, Asia Minor, and the ranges east of Hindostan, he has further generalized the phenomenon, and thereby produced a great change in geological maps, wherein many such nummulitic rocks had been laid down as being of the age of the chalk. See Journal Geol. Soc. vol. v. p. 299.

† Medals of Creation, vol. i. p. 336. Annals N. H. 2 Ser. vol. xix. p. 273.

so full of microscopic forms, that a cubic inch of the mass contains upwards of sixty thousand foraminifera.



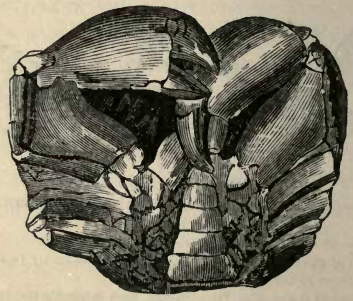
LIGN. 45.—FOSSIL SHELLS FROM THE LONDON CLAY AT PRIMROSE HILL.
(Collected and described by Mr. Wetherell.)

Fig. 1. Two specimens of *Vermicularia Bognoriensis*; natural size.
2 and 3. Portions of the same magnified, to show more distinctly two minute *Truncatulinæ* which adhere to them.
2*. Magnified views of the smaller *Truncatulina*, seen in profile and laterally.
3*. The same of the larger specimen.

38. CRUSTACEANS AND FISHES.—Of the higher order of crustaceans, as the Crabs, Lobsters, &c., many species are found in the London clay and other tertiary deposits; the greater number are extinct, or at least unknown to naturalists. As the external configuration of the shell or crustaceous covering of these animals is conformable to the soft parts it encloses and protects, the relative form and size of the principal viscera may be ascertained from the markings impressed on the outer case; and thus the character of a fossil species, and its relation to living types, may be determined by the experienced zoologist from an examination of the carapace and other parts of the shell. Many very fine specimens of fossil crabs and lobsters have been collected from the clay in the Isle of Sheppey;* some

* Medals of Creation, vol. ii. p. 512.

of which are figured and described by Mr. Parkinson * and M. Brongniart.† In the tertiary limestone of Malta a species of Crab occurs in great perfection, as exemplified in the specimen before us (*Lign.* 46). The minute crustaceans, termed *Cyprides*, which swarm in our pools, lakes, and streams of fresh water, are abundantly distributed in some of the tertiary fluviatile deposits;‡ and their congeners, *Cythere*, &c., in the marine beds.



LIGN. 46.—FOSSIL CRAB, FROM MALTA—*(half the natural size). (Cancer Macrochelus.)*

Fishes of the Tertiary Epoch. The fishes that have been collected from the various groups of tertiary strata comprise many hundred species, belonging to all the existing orders and families; but some of the most ancient forms either do not occur, or are but feebly represented.§ Nearly two hundred species are figured and described by M. Agassiz in his splendid work on fossil fishes; of which between forty and fifty belong to the universally distributed family, the Sharks. Teeth of various genera of this voracious tribe are found in

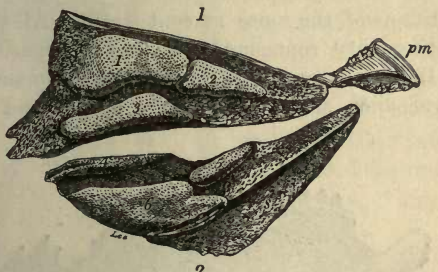
* Organic Remains of a Former World, vol. iii.; Pictorial Atlas, pl. 68, figs. 1, 3.

† Histoire Nat. Crust. Foss. pl. 8, figs. 5 and 6.

‡ Medals, vol. ii. p. 527. Jones, Monog. Tert. Entom. 1856.

§ See Genealogical table of the class Fishes, in M. Agassiz's "*Recherches sur les Poissons Fossiles.*"

abundance in numerous British localities.* In the Crag, teeth of enormous size (*Carcharodon*) are often met with; and the same species occurs in the tertiary of Belgium, Maryland, and St. Domingo. The teeth of several genera of the Ray family abound in the clays of Bracklesham, Hordwell, and the Isle of Sheppey. The jaws, covered with their dental plates, or teeth, of several species of the Eagle-rays † (*Myliobatis*) occur in the same localities: and the maxillary bones, with their tubercles, of those extraordinary fishes the *Chimæroids* have been found in a remarkably fine state of preservation at Bracklesham Bay, Highgate, Isle of Sheppey, &c.‡



LIGN. 47.—INNER VIEW OF THE UPPER AND LOWER MANDIBLES OF A CHIMÆROID FISH (*Edaphodon leptognathus*), from the Eocene clay of Bracklesham—*(half natural size)*.

1. Left side of the upper jaw.
2. Left side of the lower jaw.
pm. The left premaxillary bone.

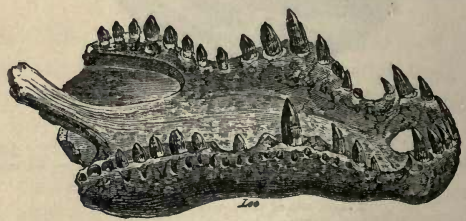
The swarms of fishes in the strata of Monte Bolca and of Aix in Provence have been already noticed, and we shall again refer (pp. 264, 269,) to these interesting localities; I may add, that a gigantic *Torpedo* has been discovered at Monte Bolca. One of the few existing species of fish known in a

* Medals of Creation, vol. ii. p. 591; Pictorial Atlas, pl. 70.
† Medals of Creation, vol. ii. p. 598. ‡ Ibid. p. 589.

fossil state is the little *Mallotus villosus*, that inhabits the shores of Iceland, and of which fossil specimens occur in nodules of indurated marl along the coasts of that island.*

As a concise expression of the Ichthyology of the tertiary epoch, it may be stated that the fossil fishes approach in their characters to the living genera, but all the species are extinct. The newer tertiaries, as the Crag, contain genera common in tropical seas, as the large sharks (*Carcharias*) and eagle-rays, &c. In the eocene or most ancient, as the London and Paris basin, Monte Bolca, &c., one-third of the Ichthyolites belong to extinct genera.

39. REPTILES OF THE TERTIARY EPOCH.—The reptiles of the Tertiary, like the mammalia, fishes, and other classes of animals, more nearly approach the recent types, than the fossil reptilians of the more ancient strata. All the orders now existing have representatives in the deposits of this epoch. In the eocene beds of England, remains of alligators, crocodiles, and serpents have been found in many



LIGN. 48.—FRAGMENT OF THE UPPER JAW OF THE ALLIGATOR HANTONIENSIS, FROM HORDWELL—(*one-fifth the natural size*).

localities;† and of the turtles or chelonians, detached bones of terrestrial tortoises, and of fresh-water and marine turtles;

* Medals of Creation, vol. ii. p. 631. See Pictet's *Paléont.* and Bronn's *Leth.* for fossil fishes.

† See Dixon's Fossils of Sussex, &c.; and Owen's Monograph of the Eocene Reptiles of England (Palæont. Soc.).

many entire specimens of the carapace and plastron have been obtained from Sheppey and Harwich. Some beautiful examples have also been met with in the Isle of Wight.* The upper jaw of an alligator (*A. Hantoniensis*), with the teeth, was found in Hordwell Cliff (*Lign.* 48);† and in the clay near Lymington I discovered many bones of a crocodile: ‡ Lady Hastings obtained a perfect skull and other parts of the skeleton of a crocodile from the same locality.

LIGN. 49.—FOSSIL BIRD, FROM MONTMARTRE.

In the miocene strata of India, Dr. Falconer found, with the colossal tortoise (p. 164), bones of other chelonians, and gavials that could not be distinguished from those of species now inhabiting India. The lacustrine deposit of Œningen (p. 268) has yielded specimens of several species of large extinct salamanders.

40. FOSSIL BIRDS. — In the gypseous building-stone of Montmartre, Cuvier found many bones possessing characters peculiar to those of birds; and after much research he was enabled to determine several fossil species, related to the pelican, sealark, curlew, woodcock, buzzard, owl, and quail. In some examples there are indications of the feathers and of the air-tubes. Sometimes the skeleton is want-

* Geology of the Isle of Wight, p. 80.

† London Journal of Geology and Palæontology, plate 1; and Owen, Palæont. Monog. 1850, p. 42, pl. 8, fig. 2.

‡ Geology of the Isle of Wight, p. 118.

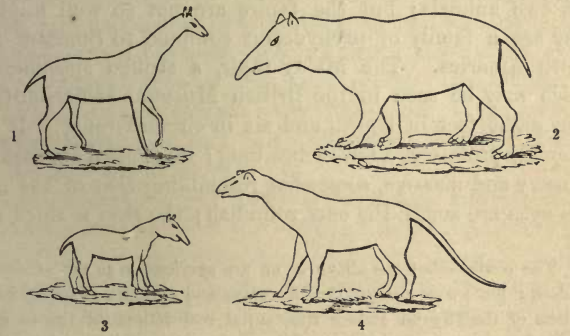
ing, and a pellicle of a dark brown substance alone points out the configuration of the original (*Lign.* 49). The leg-bones of a large bird (*Gastornis Parisiensis*), probably allied to the Waders, have been of late discovered in the lowermost tertiary beds of the Paris basin.* Three or four specimens of remains of birds have been found in the London clay. Not only are the skeletons and feathers of birds found in the tertiary strata, but even the eggs of aquatic species occur in the lacustrine limestone of Auvergne; these have probably been formed in loose calcareous debris along the borders of the lakes, in like manner as the eggs of turtles incrusted in the modern travertine, on the shores of the Isle of Ascension (p. 89), and eggs of snakes in the fresh-water limestone of Germany.

41. FOSSIL MAMMALIA OF PARIS.—We have next to consider the fossil remains of the mammalia whose skeletons were entombed in the mud of the waters which formerly occupied the site of the metropolis of France and the surrounding country. The gypsum-quarries which are spread over the flanks of Montmartre had long been known to afford fossil bones; but, though specimens occasionally attracted the notice of the naturalists of Paris, and collections were formed, no one appears to have suspected the mine of wonders which the rocks contained, until the curiosity of Baron Cuvier was awakened by the inspection of a large collection of these bones, after he had successfully applied the laws of comparative anatomy to the investigation of the fossil elephantine mammalia. He had previously paid but little attention to the partial accounts of fossil bones found in the vicinity of Paris, although in 1768 M. Guettard had figured and described many bones and teeth.

Cuvier now, however, perceived that a new world was open to his researches, and he soon obtained an extensive

* Comptes Rendus, 1855; and Quart. Journ. Geol. Soc. vol. xii. p. 204.

collection, and found himself, to use his own expression, in an ancient charnel-house, surrounded by a confused mass of mutilated skeletons of a great variety of animals. To arrange each fragment in its proper place, and restore order to these heterogeneous relics, seemed at first a hopeless task; but a knowledge of the immutable laws by which the organization of animal existence is governed soon enabled him to assign to each bone, and even fragment, its proper place in the skeleton; and the forms of beings hitherto unseen by mortal eye arose before him. "I cannot," exclaimed the illustrious philosopher, in all the enthusiasm of successful genius, "express my delight on finding how the application of one principle was instantly followed by the most triumphant results. The essential character of a tooth and its relation to the skull being determined, immediately all the other elements of the fabric fell into their proper places; and the vertebræ, ribs, and bones of the legs, thighs, and



LIGN. 50.—MAMMALIAN ANIMALS OF THE TERTIARY EPOCH.

Fig. 1. Anoplotherium (Xiphodon) gracile. 2. Palæotherium magnum. 3. P. minus 4. Anoplotherium commune.

feet seemed to arrange themselves even without my bidding, and precisely in the manner which I had predicted." The principles of comparative anatomy enunciated in the pre-

vious lecture will have prepared you for this result; and I need not dwell on the application of the laws of correlation of structure by which the animals of the Paris tertiaries have been brought to light. This group of figures (*Lign.* 50) from Cuvier's restorations is indeed a splendid achievement of Palæontology.*

The examination of the fossil teeth at once showed that the animals were herbivorous, the enamel and ivory being disposed in the manner already explained (p. 141); the crown of the tooth is composed of two or three simple crescents, as in certain pachydermata; thus differing from the ruminants, which have double crescents, and each four lines of enamel. Following out the inquiry, Cuvier at length ascertained that a great proportion of the bones and teeth belonged to two extinct genera of pachyderms, related to the tapir, rhinoceros, and hippopotamus.

Every one is familiar with the forms and habits of the last two animals; but the tapirs are not so well known; they are a family of pachyderms confined to Sumatra and South America. The Malay tapir, a stuffed specimen of which may be seen in the British Museum, sometimes attains eight feet in length and six in circumference. It has a flexible proboscis, a few inches long; its general appearance is heavy and massive, somewhat resembling that of the hog. The eyes are small, the ears roundish; the skin is thick and

* The outline-sketches above given are serviceable to the student at his desk; but we now enjoy the advantage and pleasure of seeing in the gardens of the Crystal Palace substantial restorations of the external forms of these and many others of the ancient mammalian and reptilian denizens of the earth, including the Great Deer, the Palæotherium, the Megatherium, the Iguanodon, Hylæosaurus, Megalosaurus, Ichthyosaurus, Plesiosaurus, Teleosaurus, Pterodactylus, Labyrinthodon, and Dicynodon. It is to the artistic genius of Mr. Waterhouse Hawkins, aided by his own knowledge of natural forms, and by Prof. Owen's intimate acquaintance with the structure of these extinct animals, that we are indebted for these all but living reäppearances of the great pre-Adamitic creatures.

firm, and covered with stout hair, and the tail is short. It inhabits the banks of lakes and rivers, and has been observed to walk under water, but never to swim.

42. PALÆOTHERIA AND ANOPLOTHERIA.—It is unnecessary to enter at large on the structure and habits of the animals to which these remains belonged; for even the forms of these extinct beings must be familiar to the reader, as Cuvier's restorations of their living lineaments are to be found in every popular work that treats of the ancient inhabitants of our globe.

The *Anoplotheria* are remarkably distinguished by having feet with but two toes,* as in the ruminants, and are the most ancient form of bi-hoofed animal known in a fossil state. They had an uninterrupted dental system, the teeth being placed in a continuous series, as in man, without any interval between them. The *A. commune* (*Lign.* 50, *fig.* 4) was eight feet long, and of the height of a wild boar, but of a more elongated shape; it had a long and thick tail, which must have enabled it to swim with facility, like the otter; the structure of the teeth indicates that it browsed on grass, like the horse. The *A.* (*Xiphodon*) *gracile* (*Lign.* 50, *fig.* 1), so named from its elegant proportions, was of the size and form of the gazelle, and must have lived after the manner of the deer and antelopes.

The *Palæotheria* had feet with three toes, and resembled the tapirs in the form of the head, and in having a short proboscis, but their molar teeth were more like those of the rhinoceros. Upwards of eleven species, varying from the size of the rhinoceros to that of the hog, have been discovered in the tertiary strata of France. The *P. magnum* (*Lign.* 50, *fig.* 2) was of the magnitude of a horse four or five feet high, with a massive head and proboscis, and short extremities. The *P. medium* was one-sixth smaller than the American tapir, but

* The Anoplothere is the type of Owen's *Artiodactyle* (even-toed) group, and the Palæothere of his *Perissodactyle* (odd-toed) group, of the non-ruminant ungulate herbivores.

had longer and slighter legs and feet. The *P. minus* (*fig.* 3) was an elegant creature, as large as the roebuck, with light and slender limbs.

Numerous other genera of extinct mammalia have been discovered in the eocene strata, and their characters determined by Cuvier, H. von Meyer, Owen, and others. Some are related to the animals we have just described; as the *Anthracotherium* (so named from the discovery of its remains in the anthracite or lignite of Cadibona), which held an intermediate place between the hog and hippopotamus. Six or seven species of carnivora, an opossum, a squirrel, dormouse, &c., have also been found in the Paris basin. In England, remains of several species of Palæotheria, Anoplotheria, and other characteristic genera have been discovered.*

In the miocene strata of Touraine and of Darmstadt, remains of similar extinct mammalia, together with those of the Dinotherium and Mastodon, are found associated with those of existing genera.

43. FOSSIL MONKEYS.—The illustrious Cuvier, when commenting on the extraordinary fact, that among the innumerable relics of the mammalia which peopled the continents and islands of our planet during the tertiary ages, no traces of man or of his works occur, emphatically observed, that it was a phenomenon not less surprising, that no remains of the quadrumanous tribes, which rank next to the human race in physical conformation, should have been discovered; and that the circumstance was the more remarkable, because the majority of the mammalia found in the drift and tertiary deposits have their congeners at the present time in the warmest regions of the globe, in those intertropical climates where the existing quadrumana are

* See Prof. Owen's British Fossil Mammalia; and the Geology of the Isle of Wight, p. 83. The mammalian remains here alluded to comprise the Palæothere, Anoplothere, Chœropotamus, and Dichobune, from the Bembridge beds, two species of Hyopotamus from the Hempstead series, and other genera from Hordwell, the London clay, &c.

almost exclusively located.* At length proofs were obtained, and almost at the same time in France, India, South

1 2 3

LION. 51.—PORTION OF THE LOWER JAW OF A MONKEY; FROM EOCENE SAND AT KYSON, NEAR WOODBRIDGE.†

(Magnified two diameters.)

Fig. 1.—The outer side of the tooth and jaw.
2.—View of the specimen from above, showing the upper surface of the crown of the tooth.
3.—View of the inner side.

America, and England, of the existence of this order of animals during the most ancient tertiary epochs.

The fossil remains are referable to four modifications of the existing types of quadrumana. Those from France ‡ belong to animals of the Ape tribe; those from England to the *Macacus;* the Indian fossils to a species of the long-limbed and tailed monkeys, of which the Negro monkey is an example; and the relics from South America to a gigantic Capuchin monkey.§

* Discours sur les Révolutions, p. 171.

† From the Magazine of Nat. Hist. vol. iii. p. 447.

‡ Three in number, *Pliopithecus antiquus*, *Dryopithecus Fontani*, and *Semnopithecus monspessulanus*. The fossil ape of Pikermi, in Greece, not long since discovered, is named *Semnopithecus pentelicus* by M. Lartet.

§ THE QUADRUMANA OR MONKEYS.—These animals come nearest to

One of the British specimens (*Macacus eocænus, Lign.* 51) was found in a bed of eocene sand, at Kyson or Kingston, a few miles east of Woodbridge in Suffolk, and another (*M. pliocænus*) at Grays in Essex.*

44. TERTIARY STRATA AT AIX.—A group of strata remarkable for its organic remains occurs near Aix, a town in Provence, which is situated upon a thick deposit of tertiary conglomerate. The series on the northern side of the valley consists of—1. Tertiary breccia, the lowermost bed, which forms the site of the town of Aix. 2. Marl, with fishes and insects. 3. Gypsum and gypseous marls, containing fishes and insects, leaves of palms and other plants, and fresh-water univalve and bivalve shells, particularly a species of *cyclas*, in great abundance.† 4. Fresh-water

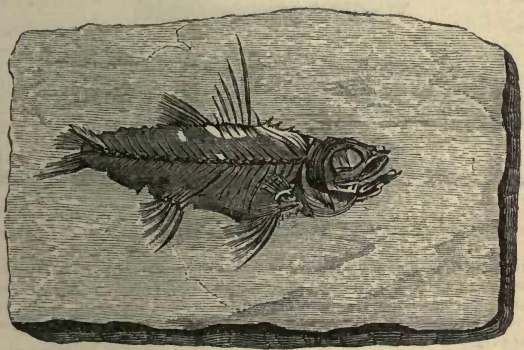
man in the form and proportion of their skeleton and of their separate bones, in the general disposition of their muscular system, and its adaptation for a semi-erect position of the body, in their great cerebral organization, the perfection and equable development of their senses, their intellectual capacity and complicated instincts. These most elevated of all inferior animals are fitted to select, obtain, and digest the succulent ripe fruits of trees, and are destined to inhabit the rich and shady forests of tropical climates. They leave to the squirrels and the sloths the buds and leaves; to the ponderous elephant and rhinoceros the branches and the stem; and to the beavers and other rodentia the hard bark of the trees. Their delicate organization is adapted only for the richest products of the vegetable kingdom; and the soft and nutritious quality of their food is suitable to the broad enamelled crowns of their molar teeth, which are studded with rounded tubercles: their stomach is simple. With a high cerebral and muscular development, corresponding with their elevated rank in the scale of beings, and the position of their food, they are the most agile and sportive of all mammalia; and they are provided with prehensile organs at every point; their teeth, tail, feet, and hands assist in their agile movements, and in their boundings from branch to branch, and from tree to tree.—*Dr. Grant's Lectures on Comparative Anatomy.*

* See Owen's British Fossil Mammalia; and the Medals of Creation, vol. ii. p. 815.

† The *Cyclas* inhabits rivers, lakes, and marshes, and therefore denotes the fluviatile or lacustrine origin of the deposits.

limestone. To the south, extending towards Toulon, are lacustrine strata of red marl, with compact limestone enclosing shells, gyrogonites, &c.; still farther to the south, beds of grey fresh-water limestone appear; and at Fuveau, a series of blue limestones, shales, and coal is extensively worked. Fresh-water shells, and seed-vessels of *Charæ*, with other vegetable remains, occur in abundance in the coal-beds and intermediate layers of shale.

The marls are finely laminated, and contain insects and fishes in a remarkable state of preservation. The fishes are very numerous; one small species especially (*Smerdis minutus*, *Lign.* 52), which occurs in shoals, and is found grouped in every variety of position.

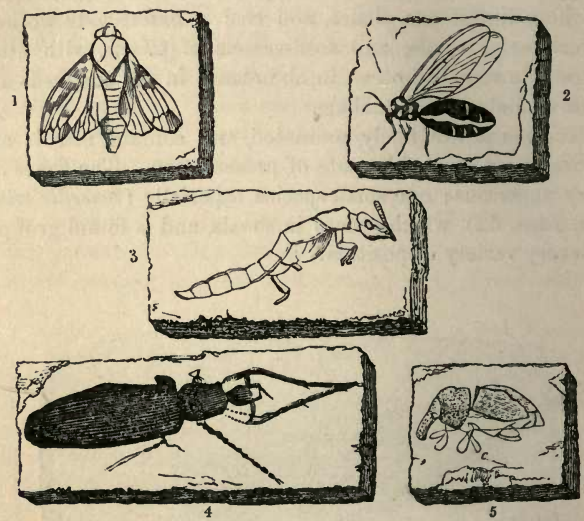


LIGN. 52.—FOSSIL FISH, FROM AIX. (*Nat. size.*)
(*Smerdis minutus.*)

This elegant little fish belongs to a genus of the tribe of Percoids, with two dorsal fins and seven branchiostegous rays. It is about the size of a perch a year old.

45. FOSSIL INSECTS.—But the most extraordinary relics are the fossil insects, which appear as fresh as if enveloped

but yesterday. A few of the most interesting forms are here delineated (*Lign.* 53), on a slightly enlarged scale, from



LIGN. 53.—FOSSIL INSECTS FROM THE TERTIARY STRATA AT AIX, IN PROVENCE.

Fig. 1. *Tettigonia spumaria.* 2. *Mycetophila*, imbedded apparently while in the act of walking; the articulations of the body distended by pressure. 3. *Lathrobium.* 4. Allied to *Penthetria holosericea.* The hinder legs are broken off, and one of them is reversed, so that the *tarsi* nearly touch the thigh; the *palpi* are long and perfect; the *antennæ* are remarkably distinct. 5. *Liparus*, resembling *L. punctatus.*

the plate accompanying a memoir "On the Fresh-water Formation of Aix, in Provence," by Murchison and Lyell.*

All these insects belong to existing genera, and only one species is aquatic.† The anterior *tarsi* are generally obscure, or distorted; but in some specimens the claws are

* Jameson's New Edinburgh Journal, for 1829, vol. iii.

† Principles of Geology, Edit. 5, vol. iv. p. 211.

visible, and the sculpture, and even a degree of local colouring, are preserved. The nervures of the wings in the *Diptera*, and the pubescence on the head, are distinctly seen. Several of the beetles have the wings extended beyond the *elytra*, as if they had fallen into the water while on the wing, and had made an effort to escape by flight. M. Marcel de Serres has enumerated nearly seventy genera of insects, and a few *Arachnides*, or spiders. The most curious fact is, that *some of the insects are identical with species which now inhabit Provence*. It seems probable that these insects were brought together from different localities by floods and mountain-streams; yet, as Mr. Curtis observes, all of them might have inhabited moist and shady forests. The laminated marls contain also the coverings of the little fresh-water crustacean, called *Cypris*, which swarms in our pools and stagnant waters, and must be familiar to all who have seen the exhibition of the oxy-hydrogen microscope; living cyprides being commonly shown, and appearing somewhat like the head and feet of a flea protruding from an oval case or bivalved shell, and swimming by means of the fine pencils of hair that are attached to their front limbs. These crustaceans are said to shed their cases annually; and the surface of the mud spread over the bottoms of lakes is often covered with their relics. The marls of Aix, as well as of many other fresh-water formations, abound in fossil *Cyprides*, which oftentimes constitute entire seams or thin layers.

The seed-vessels of the *Chara*, a common plant in our ditches and ponds, also occur in profusion; they were formerly supposed to be shells, and from their peculiar structure received the name of *gyrogonites*, which they still bear, although their real nature has long since been ascertained.* In conclusion, Murchison and Lyell observe to the

* See Medals of Creation, vol. i. p. 196; or, Geology of the Isle of Wight, p. 78.

effect that this tertiary series differs essentially from that of the London and Paris basins: and that the great development of regular beds of blue limestone and shale, the quality and appearance of the coal, and the thickness of the compact, grey, brown, and black argillaceous limestones and sandstones, together with the red marls and gypsum, give them the aspect of the most ancient of our secondary rocks; and it is only by the occurrence and peculiar species of fluviatile and lacustrine shells, the seed-vessels of the charæ, &c., that the comparatively recent date of the whole group is demonstrated.

46. FOSSIL FOX OF ŒNINGEN.—Among the tertiary lacustrine formations of the Continent, there is one so much celebrated for its organic remains as to require a passing notice. Œningen, near Constance, has for centuries been known to afford fossil remains of great beauty and interest. A short but lucid memoir by Sir R. Murchison * presents in a few lines the history of this ancient lake. The Rhine, in its course from Constance to Schaffhausen, flows through an area of tertiary marine deposits, known by the name of *Molasse*, which forms hills on both sides of the river, of from 700 to 900 feet in height. In a depression or basin of this molasse, is a series of strata composed of marls, and cream-coloured, fine-grained, fetid limestone, with laminated white marl-stone, forming a total thickness of thirty or forty feet. In the marl-stone, leaves and stems of plants, insects, shells, crustacea, fishes, turtles, a large aquatic salamander, birds, and a perfect skeleton of an animal, allied both to the common fox and to the civet, have been discovered.

This last-mentioned fossil (the *Galecynus Œningensis* of *Prof. Owen.* See Quart. Geol. Journal, vol. iii. p. 55) was purchased by Sir R. Murchison,† for whom I developed it,

* Geological Transactions, 2nd Ser., 1832, vol. iii. p. 289.

† By the liberality of this gentleman, one of the two corresponding

and removed the stone with which the bones were more or less incrusted, so as to expose the entire skeleton, which bears much resemblance to a common fox; it was figured and described by me in the Geological Transactions for 1832, vol. iii. p. 291, pl. 33, 34.

A tortoise, three feet in length, with the cranium and bones of the neck, tail, and three of the pats, well preserved, has since been discovered. Sir R. Murchison concludes that these fresh-water deposits are the contents of a lake, belonging to the newer or the middle tertiary epoch; and that the period of their formation must have long preceded the present condition of the country, for they contain some unknown species of animals, and the Rhine has worn a channel through them to the depth of several hundred feet.

47. Fossil fishes of Monte Bolca.—Another interesting assemblage of tertiary strata is exposed in the celebrated quarries of Monte Bolca, that are situated on the borders of the Veronese territory, about fifty miles N.N.W. of the lagunes of Venice. These deposits form part of a range of hills of moderate elevation; volcanic deposits abound in the neighbouring Vicentin, and the summit of the hill at Monte Bolca is capped with basalt.* This hill is principally composed of argillaceous and calcareous strata, with beds of a cream-coloured fissile limestone, which readily separates into laminæ of moderate thickness, and abounds in fishes in the most beautiful state of preservation. They are all compressed flat, but the scales, bones, fins, and even the muscular tissue remain; their colour is a deep brown, thus admirably contrasting with the limestone in which they are imbedded. Several hundred species are contained in these quarries, and thousands of specimens have been collected; according to M. Agassiz, all the species, though related to

slabs in which this unique fossil is imbedded has been presented to the Geological Society, and the other to the British Museum.

* Organic Remains of a Former World, vol. iii. p. 247.

the recent, are extinct.* From the immense quantities which occur in so limited an area, it seems probable that the limestone in which they are imbedded was a limey mud erupted into the ocean by volcanic agency; and that the fishes were thus suffocated, and surrounded by the calcareous mass. Nor is this hypothesis without support; for on the appearance of a volcanic island in the Mediterranean, a few years since, hundreds of dead fishes were seen putrid and floating in the waters; and it cannot be doubted that shoals of fishes may at the same time have been enveloped in the volcanic matter at the bottom of the sea, and become compressed and preserved; and when the mud which envelopes them is consolidated, and the bed of the Mediterranean elevated above the waters, these fishes may resemble the ichthyolites of Monte Bolca.†

48. TERTIARY VOLCANOS OF FRANCE.—In the former lecture I alluded to volcanic action as still in activity, and as having been equally energetic in more ancient periods; and there is abundant proof, that during the immense lapse of time comprehended between the earliest and the latest of the tertiary formations, the internal fires of our globe were not dormant. We have already had occasion to remark how rarely the former geographical relations of a country are preserved, and that, though we may be able to pronounce with certainty that this spot was once dry land,—that yonder flowed a river,—that here is the bed of an ancient sea,—yet we can seldom determine the limits of the one, or trace the boundaries of the other. But there is one remarkable exception — a district, where the most striking geological revolutions have taken place, and yet the area of those changes still maintains its ancient physical geography—that district is Auvergne, a province in central France.

* See Recherches sur les Poissons Fossiles.

† See Lecture VIII.

Nearly a century since, two French academicians, MM. Guettard and Malesherbes, on their return from an exploration of Vesuvius, arrived at Montelimart, a small town on the left bank of the Rhone, where Faujas St. Fond, a distinguished naturalist, was sojourning. These savans were struck with the remarkable character of the pavements of the streets, which were formed of short joints of basaltic columns, placed perpendicularly in the ground; and upon inquiry they found the stones had been obtained from the neighbouring mountains of the Vivarais. This information induced them to survey the country; and upon arriving at Clermont, the capital of Auvergne, a town with about 30,000 inhabitants, they were satisfied that the whole region was of volcanic origin; for in the vicinity of that town they discovered consolidated currents of lava, black and rugged as those of Italy, extending uninterruptedly into the plains below, from some conical hills of scoriæ, which still preserved the form of craters.* "To those who now visit central France, and see everywhere unequivocal marks of volcanic agency,—the numerous hills formed entirely of loose cinders, porous and diversified as if just thrown from a furnace, and surrounded by plains of rugged lava, on which even the lichen refuses to vegetate, — it appears scarcely credible, that previously to the last half century no one had thought of attributing these marks of desolation to the only power in nature capable of producing them. This, however, is perfectly natural, and not without examples. The inhabitants of Herculaneum and Pompeii built their houses with the lava of Vesuvius, ploughed up its scoriæ and ashes, and ascended its crater, without dreaming of their proximity to a volcano which was to give the first proof of its energies by burying them beneath its eruptions; and the Catanians regarded as a fable all mention of the former activity of

* Recherches sur les Volcans éteintes du Vivarais: par M. Faujas St Fond. Paris, 1778.

Etna, when, in 1669, half their town was overwhelmed by its lava-currents." *

49. EXTINCT VOLCANOS OF AUVERGNE. (Plate II.) — The country which is the site of these extinct volcanos is about 220 miles south of Paris, and forms a vast plain, situated in the Department of the Limagne d'Auvergne. It is so remarkable for its fertility, that it is called the Garden of France; a quality attributable to the detritus of the volcanic rocks, which enters into the composition of the soil. It is enclosed on the east and west by two parallel ranges of gneiss and granite. Its average breadth is twenty miles, its length between forty and fifty, and its altitude about 1200 feet above the level of the sea. The surface of this plain is formed of alluvial deposits, composed of granitic and basaltic pebbles and boulders, reposing on a substratum of limestone. Hills, of various elevations, composed of calcareous rocks, are scattered over the plain; and the river Allier flows through the district, over beds of limestone and sandstone, except where it has excavated a channel to the foundation-rock of granite. The hills formed of calcareous alluvial deposits are the remains of a series of beds, which once constituted an ancient plain, at a higher elevation than the present. Many are surmounted by a crest or capping of basalt, to which their preservation is probably attributable; others have escaped destruction from being protected by horizontal layers of a durable limestone, which I shall presently describe.

We have, then, as the ground-plan of the district, an ex-

* Geology of Central France, by G. Poulett Scrope, Esq., F.R.S., 4to, with fol. Atlas, 1827. In 1815, Professor Playfair visited Auvergne, and concisely described the volcanic phenomena there exhibited. Mr. Bakewell, in 1832," drew attention to this remarkable district in his "Travels in the Tarentaise," 2vols. 8vo, 1823; and subsequently Daubeny, Scrope, Lyell, and Murchison published highly interesting memoirs on the geological phenomena of Auvergne, which have also been extensively illustrated by foreign authors.

tensive plain, chequered with low hills of fresh-water limestone, which are capped with compact lava (*Pl.* II. *fig.* III.); the boundaries of this tract being formed of ranges of crystalline rocks, 3000 feet in altitude. To the westward the limestone disappears, and a plateau of granite rises to a height of about 1600 feet above the valley of Clermont, being 3000 feet above the level of the sea. This supports a chain of volcanic cones and dome-shaped mountains (*Pl.* II. *fig.* II.), about seventy in number, varying in altitude from 500 to 1000 feet from above their bases, and forming an irregular range nearly twenty miles in length, and two in breadth. The highest point of this range is the Puy * de Dome, which is, 4000 feet above the level of the sea (*Pl.* II. *fig.* II.), and is composed entirely of volcanic matter; it possesses a regular crater, 300 feet deep, and nearly 1000 feet in circumference. Many of the cones of the range retain the form of well-defined craters, and their lava-currents may be traced as readily as those of Vesuvius. The Puy de Pariou is a most perfect example: it is a cone covered with fine turf, both on the ascent and within the crater; the latter is a mile in circumference, and very deep, sloping downwards at an angle of 30°. From the lower part of the cone a current of lava, which is still rugged and black, has issued; and the plain is covered with scoriæ and volcanic cinders, which are exposed to the depth of twenty feet in the ravines made by the winter-torrents.

50. Crater of Puy de Come. — One of the most remarkable cones is the Puy de Come, which rises from the plain to the height of 900 feet; its sides are covered with trees, and its summits present two distinct craters, one of which is 250 feet in depth. A stream of lava may be seen to have issued out from the base of the mountain; and at a short distance, from having been obstructed by a mass of

* *Puy* is the name given in this province to an insulated conical hill.

granite, it has separated into two branches; these can be traced along the granitic platforms, and down the side of a hill into an adjacent valley, where they have dispossessed a river of its bed, and constrained it to work out a fresh channel between the lava and the granite of the opposite bank. Another cone rises to the height of 1000 feet above the plain, having a crater nearly 600 feet in vertical depth, and a lava-current, which first falls down a steep declivity, and then rolls over the plain in hilly waves of black and scorified rocks. In one part of this volcanic group is a circular system of cones, apparently the produce of several rapidly succeeding eruptions. "The extraordinary character of this scene impresses it for ever on the memory; for there is, perhaps, no spot, even among the Phlegræan fields of Italy, which more strikingly displays the characters of volcanic desolation.* Although the cones are partially covered with wood and herbage, yet the sides of many are still naked; and the interior of their broken craters, rugged, black, and scorified, as well as the rocky floods of lava with which they have loaded the plain, have a freshness of aspect, such as the products of fire alone could have so long preserved, and offer a striking picture of the operation of this element in all its most terrible energy." † The accompanying sketches,‡ in Pl. II., will illustrate these remarks.

Plate II. *fig.* III. A view of the environs of Clermont. In front is a basaltic peak, crowned by the Castle of Montrognon; and beyond are basaltic platforms (indicated by the dark lines of shade) on hills of limestone. The town is seen in the plain or basin, which has been excavated by aqueous agency, since the deposition of the strata which form

* Plate II. represents a part of this chain of extinct volcanic rocks; with Mont Dome in the distance.

† Scrope's Geology of Central France.

‡ The delineations are reduced from the elaborate and beautiful drawings of Mr. Scrope.

the surrounding hills. In the distance is the escarpment of old crystalline rocks, forming part of the boundary of the volcanic district.

Fig. II. Part of the southern volcanic chain of Puys, exhibiting the broken craters of Chaumont; from the bases of several the cooled lava-currents still remain as when they issued. Mont Dome appears in the distance.

This region affords, too, a striking illustration of the erosion of the surface of a country by alluvial action. The thickness of the volcanic mass is between 300 and 400 feet; it is composed of two distinct beds of basalt, separated by a layer of scoriæ and volcanic fragments. Many portions, both of the upper and lower beds, are made up of well-defined, vertical, polygonal columns. The streams of lava to which these plateaux belong have been traced for more than thirty miles; they rise in a narrow ridge across the crystalline heights, and then spread over, and lie comformably upon, the secondary formations. The limestone beneath the basalt is, in some places, covered with vegetable soil containing a common species of terrestrial shell (*Cyclostoma elegans*). The nearly horizontal disposition of the basalt, its columnar structure, and position on the limestone, into which it has injected veins and dikes, render it, as Mr. Scrope observes, very analogous to the ancient volcanic rocks of Ireland, (which will be described in a future Lecture).

51. MONT DORE (*Pl.* II. *fig.* 1). In the same province there is another remarkable system of extinct volcanos connected with the Puy de Dome. While, in the district I have just described, the old rocks are only partially obscured by the volcanic products, in Mont Dore the granitic foundation, over an area of many miles in extent, is entirely covered by them, and the erupted masses attain a considerable elevation. Mont Dore is a mountainous tract, the highest

portion of which is about 6000 feet in altitude.* It consists of a group of seven or eight rocky summits, which form a zone a mile in diameter, the whole consisting of a succession of beds of volcanic origin. It is deeply channelled by two principal valleys, and furrowed by many minor water-courses, all originating near the central eminence, and diverging towards every point of the horizon. The beds of which this group is composed consist of scoriæ, pumice-stone, trachyte, and basalt; these rocks dip off from the central axis, and lie parallel to the sloping flanks of the mountain, as is the case in Etna, the Peak of Teneriffe, and all other insulated volcanic mountains. There is no regular crater; the summit of Mont Dore presenting a broken outline; but streams of lava may be traced, in elevated peaks, over a gorge which occupies the very heart of the mountain, and they extend to a distance of many miles. A remarkable natural section, worn by a cascade, at a short distance from the baths of Mont Dore, exhibits the following beds in a descending series:

1. Porphyritic trachyte; a volcanic rock, 160 feet in thickness. 2. Arenaceous tufa. 3. Columnar basalt. 4. Breccia, made up of volcanic fragments, cemented together by tufa. 5. Thick beds of basalt. 6. White ferruginous tufa, enveloping fragments of granite, basalt, &c., and traversed by veins of the overlying basalt.

I may add, that the volcanic vents of central France are evidently of very different ages; some being of immense antiquity, while others are of comparatively recent origin, for they have exploded through the oldest beds of basalt; but even the most modern belong to a very remote period.

* Pl. II. fig. 1. is a profile of Mont Dore as seen from a distance, from a sketch by M. Constant Prevost: the dotted outline shows the presumed form of the cone when it was in activity; a ground-plan of the broken crater is annexed

52. FRESH-WATER STRATA OF AUVERGNE.—This district presents a series of alternations of fresh-water limestones, with basalt, scoriæ, and other volcanic productions, based on a foundation of granite and gneiss. These beds occur in the following order, beginning with the lowest or most ancient:—

1st. Clay, sand, and breccia, without organic remains.

2nd. Limestone and calcareous marl, in strata nearly horizontal; about 900 feet thick. These are entirely of fresh-water origin, for they abound in shells of the genera *potamides*, *helix*, *planorbis*, and *limnæa*, which are known to inhabit lakes and rivers. Some of the beds contain bitumen; others are entirely made up of the tubular cases of the caddis-worm, the larva of the caddis-fly (*Phryganea*), cemented together by calcareo-siliceous matter. These tubes or cases, which are formed by the adhesion of small shells, and occasionally of other substances, to the outer surface of the silken case secreted by the insect, are abandoned by the animal when its metamorphosis is completed, and layers of them may often be seen in our ditches and lakes. The fossil cases (*Indusia tubulata*) have been cemented together by calcareous infiltration, and form a compact stone, which is employed for building. The attached shells are so minute, that often more than a hundred are affixed to a single case; and a cubic inch of the limestone includes ten or twelve tubes. If, says Mr. Scrope, we consider that repeated strata, of five or six feet in thickness, almost entirely composed of these fossils, once extended over the whole plain of the Limagne, occupying a surface of many hundred square miles, we may have some idea of the countless myriads of minute beings which lived and died within the bosom of that ancient lake.

In the limestones, associated with land and fresh-water shells and remains of terrestrial plants, are bones of species of palæotherium, anoplotherium, lagomys, marten, dog, rat, tortoise, crocodile, serpent, and birds; * the lava-currents that have flowed over the strata have produced but little change in the organic re-

* For general and detailed notices of the paleontology of Auvergne, see M. Pomel's Memoirs in the Bulletin of the Geological Society of France, and in the Journal of the London Geol. Soc. vol. iii. part 2, p. 61. See also Congrès Scient. France, Puy, 1855, vol. i.

remains. This series comprises beds of gypseous and laminated marls, with intercalations of siliceous limestone, containing impressions of lacustrine and river shells. In some localities, the fresh-water limestone has an intermixture of volcanic matter, and presents the characters of a sediment slowly and tranquilly deposited in a lake, into which ashes and fragments of rocks and scoriæ were projected by a neighbouring volcano; while some beds appear to have been formed by a violent intrusion of volcanic products.

3rd. Immense beds of basalt, scoriæ, &c., spread over the tabular masses of fresh-water limestone, and often capping the summits of the lower hills. (Pl. II. fig. III.)

4th. Sand and gravel, containing bones of the mastodon, elephant, hippopotamus, rhinoceros, tapir, horse, boar, hyena, bear, dog, beaver, hare, &c.; with these are associated lignite, and other vegetable remains. Some of the beds of limestone abound in seed-vessels of charæ; and the laminated clays contain fishes, with leaves and stems of reeds and other plants.

There are several incrusting springs in Auvergne, largely impregnated with carbonic acid, which have deposited immense quantities of calcareous tufa. These issue from fissures in the granitic and gneissic rocks that form the base of the whole territory, and are spread over the volcanic foci whence these mineral waters, in all probability, originate; numerous thermal springs also occur throughout the district.

53. SUCCESSIVE EPOCHS OF MAMMALIA.—The fossil remains of mammalia found in the sedimentary deposits of the volcanic region of Auvergne are very numerous, and comprise many of the most ancient species of the Paris basin, as well as those of existing ones. They are separated by Lyell and other eminent observers into three groups:—

I. Mammalian remains from the fresh-water strata overlying the granite; these comprise bones of palæotheria, anoplotheria, and other Cuvicrian pachyderms, associated with extinct species of rhinoceros, horse, deer, &c.; this is the most ancient group.

II. Bones of mastodon, hippopotamus, elephant, horse, tapir, deer,

antelope, and many other terrestrial quadrupeds, all supposed to be extinct forms; associated with existing species of fresh-water shells. These are from the lacustrine deposits, which are separated from the above by ancient lava-currents (*basalt*)

III. Fossil bones from the beds of sandy marl, and alluvial debris. These are referable to small Rodents (*Lagomys*), and nearly fifty species of other existing mammalia; as mouse, squirrel, hare, marten, dog, cat, hog, ox, deer, and horse; also frogs, lizards, snakes, and birds; of the latter, even the eggs are occasionally found.

54. SUMMARY OF THE GEOLOGICAL PHENOMENA OF AUVERGNE.—In the calcareous and siliceous limestones of Auvergne, and their associated laminated marls, gypsum, lignite, and conglomerate, we have a general analogy with the older fresh-water tertiary formations of Paris; the shells and plants being similar, and the quadrupeds of the same genera. And, if we suppose the Paris basin to have been elevated above the water during the active state of neighbouring volcanos, and that successive streams of lava flowed over its sedimentary deposits, we should have a series of phenomena resembling those of Auvergne; with the exception, that the presence of marine remains would denote that the basin had been filled with salt water, and communicated with the sea. The facts submitted to our notice appear to establish the following sequence of physical events.

1st. The elevation, after the deposition of the secondary limestones, of the whole area of the old crystalline rocks which form the foundation of central France.

2ndly. A period of tranquillity, during which fresh-water lakes occupied the irregular hollows of the district; the neighbouring country being inhabited by palæotheria, anoplotheria, and other extinct mammalia, whose bones, together with the relics of the then existing vegetation, and the shells of mollusca, became enveloped in the tranquil depositions that were going on in the lacustrine basins.

3rdly. Another elevation of the district took place, a new system of lakes was established, and the country was again clothed with forests, and was inhabited by deer, oxen, rhinoceroses, and hyenas, many

of the skeletons of which became imbedded in the sediments of the waters.

4thly. The volcanos became active; explosions took place through hundreds of vents; trachyte and basalt were ejected, and in some places pierced the fresh-water deposits, while in others they overspread them with sheets of lava. Vegetation still flourished, and the remains of plants were entombed in the volcanic products.

5thly. Another period of tranquillity—the rivers and other water-courses, dammed up or deranged by the lava-currents, formed new channels, and accumulated beds of gravel, sand, and clay. Deer, horses, oxen, &c., with hyenas and other carnivora, inhabited the district; having for contemporaries terrestrial mammalia of species which exist in Auvergne at the present time. Volcanic eruptions succeeded, and continued until a comparatively recent period.

Lastly. Streams and rivers of later date, and which still effect the drainage of the country, began to wear away channels through the beds of lava and limestone to the crystalline rocks beneath, and intersect the country with valleys and ravines, spreading over the ancient beds a thick covering of alluvial soil.*

55. EXCAVATION OF VALLEYS BY STREAMS AND RIVERS.—There is no district which exhibits in more striking characters the erosive power of running water, than Auvergne. In many places the basalt is columnar, like that of Staffa and the Giants' Causeway; and one range, on the banks of the Ardêche, forms a majestic colonnade 150 feet in height, extending a mile and a half along the valley which has been channelled out by the river that flows at its base.

Mr. Scrope's description of this process is highly picturesque. "The bed of the Ardêche is strewed with basaltic boulders, pebbles, and sand, originating from the destruction of the columnar ranges. In some of the volcanic cones the beds of basalt may be traced issuing from the crater and following the inequalities of the valley, just as a stream of lava would follow down the same course at the present

* This account of the volcanic phenomena of Auvergne is an abstract of the interesting Essays of Messrs. Bakewell, Scrope, Lyell, Murchison, Daubeny, Hibbert, Croizet, Jobert, Robert, and Bertrand-Roux. Mr. Scrope's work cannot be perused, even by the general reader, without deep interest.

time. Yet these ancient lava-currents have subsequently been corroded by rivers which have worn through a mass of rock 150 feet in height, and formed a channel even in the gneiss-rocks beneath, since the lava first flowed into the valley. In another spot, a bed of basalt, 160 feet high, has been cut through by a mountain-stream, and very beautiful columnar masses are exposed. The vast excavations effected by the erosive power of water along the valleys which feed the Ardèche, since their invasion by lava-currents, prove that even the most recent of these volcanic eruptions belong to an era incalculably remote."

56. EXTINCT VOLCANOS OF THE RHINE.—I have dwelt so long on the Phlegræan fields of Auvergne, that but a brief space can be afforded to another group of tertiary volcanos. Every one who has ascended the Rhine will remember where

> "The castled crag of Drachenfels
> Frowns o'er the wide and winding Rhine,"

FIGN. 54.—THE DRACHENFELS.

forming one of the Siebengebirge, or Seven Mountains, whose majestic and graceful forms suddenly burst on the

sight, rising from the level plains on the right bank of the river to an altitude of nearly 1500 feet. These picturesque objects belong to a group of extinct volcanos; while, on the opposite side of the river, the Eifel, with its craters covered with scoriæ and cinders, and lava-currents still distinctly visible, attests the wide area over which those ancient fires once extended. Unlike the district we have just noticed, the foundation-rock of the country is an ancient sedimentary deposit, consisting of coarse red sandstone and slate, thrown into a highly inclined position. Through these beds the volcanic eruptions, consisting of trachyte, basalt, and other modifications of trap-rocks and scoriæ, have forced their way. The basalt is black, and very compact, and breaks into sharp fragments; it is frequently columnar, and the separate hexagonal pillars are made use of for posts and pavements, in the adjacent towns. Such, says Mr. Horner,* is the profusion of basaltic pillars, that the walls of the town of Linz are wholly built of these materials, placed on their sides, with the ends projecting outwards. The streets are paved with the smaller columns set on end, thus forming a miniature representation of the Giants' Causeway; and the same volcanic product forms a large proportion of the walls of Bonn and Cologne. The secondary strata are covered by a series of tertiary deposits, consisting of sand, sandstone, clay, and lignite; constituting what is termed a *brown-coal formation*. Upon these deposits is an extensive layer of gravel, which is covered by a deep bed of loosely coherent sandy loam or mud, provincially termed *Loess*. This fine earthy detritus, which contains recent species of terrestrial and fresh-water shells, forms the

* On the Geology of the Environs of Bonn, by Leonard Horner, Esq., F.R.S. Geological Transactions, 2nd Ser., vol. iv., 1836, p. 433. See also the comprehensive paper by W. J. Hamilton, Esq., F.R.S., on the Brown-coal and other tertiary formations of Germany, in the Quart. Journal of the Geol. Soc. vol. x. p. 254.

subsoil of the vast plains in which Bonn and Coblentz are situated, and extends as far as the falls of Schaffhausen.

57. BROWN-COAL FORMATION.—As the usual condition in which bituminized vegetable matter occurs in the tertiary formations is well exemplified in the brown-coal, or *lignite*, of the Rhine, it will be instructive to examine the characters of this deposit somewhat in detail; for we shall thereby obtain data which will prepare us for the investigation of the ancient carboniferous system. This formation, which is spread over a great extent of country on both sides of the river, consists of clay, sand, sandstone, conglomerates, clay, and ironstone, with lignite, or bituminized wood, of various qualities, disposed in distinct beds, and intermixed with argillaceous matter. The breadth of the ridge of low hills formed by this assemblage of strata, on the left bank of the Rhine, is from three to five miles, its elevation varying from 50 to 200 feet.

The lignite occurs in the following states:—1. A black earthy and pulverulent substance. 2. Concretionary masses, with leaves and fragments of wood. 3. Wood in various degrees of bituminization, and of different shades of colour, from a light-brown to jet-black. 4. Very finely laminated masses of bituminous matter and clay, of a dark chocolate-colour, and separating into elastic flakes, as thin as paper, whence its name *papierkohle;* this substance is so highly bituminous as to burn with a bright flame. The wood is generally in small fragments, but stems of large trees, somewhat compressed, occasionally occur; in some instances the trees are imbedded in an upright position, having the roots attached, and the stems passing through several beds of lignite. In many examples the wood is so little changed, that, like the timber of our peat-bogs, it is employed in building; in others it is highly pyritous, that is, impregnated with iron-pyrites or sulphide of iron,* like the fossil vegetables of

* More correctly "bisulphide;" "sulphuret" is obsolete.

the Isle of Sheppey. It is for the most part dicotyledonous; but leaves of palms occasionally occur; and foliage resembling that of species of Cinnamomum and Podocarpus has likewise been discovered.*

Mr. Horner is of opinion that there were extensive fresh-water lakes, in the sediments of which trees and plants, drifted by land-floods, were ingulfed; and that volcanic eruptions were simultaneously going on, in the same manner as in the modern submarine volcanos. There is a great fault, or dislocation, in this brown-coal formation, which he suggests may be attributed to a powerful and sudden volcanic explosion, that probably occasioned the elevation of the Siebengebirge, and raised up that portion of the coal-beds which reposes on the flanks of those peaks. The gravel covering the lignite must have been strewn over the plain previously to this elevation, for it is found on both sides of the river at a great height, and not in the intermediate plain. These inductions are so evident as to require no comment.

Sir Charles Lyell observes, that the most striking peculiarity of a great many of the newer lake-craters of the Eifel is the absence of any signs of lava, or even of torrefaction, in their walls, when these are composed of regular strata of ancient sandstone and shale. The summits of hills formed of these rocks have evidently in some instances been swept away by gaseous explosions, while no lava, and scarcely any scoriæ, has escaped from the newly formed cavity. No feature in the Eifel volcanos is more remarkable than the proof they afford of enormous aëriform discharges, accompanied by very scanty eruptions of melted matter. I know of no other extinct volcanos, says this author, where gaseous explosions of such magnitude have been attended by the emission of so small a quantity of lava.†

* Geol. Trans. 2 Ser. vol. iv. p. 452.

† Manual of Geology, p. 548.

The ancient alluvial deposit called the *Loess* is a fine loam, containing fresh-water and land shells of many existing species; a few bones of the horse and mammoth are almost the only mammalian remains that have been discovered.* From the extensive distribution of this bed, and its occurrence at various elevations—in some instances on the flanks of mountains 1200 feet above the level of the sea, at others spread out over the gravel of the vast plain of the Rhine, it is inferred, that, although the *loess* has been deposited since the existing system of the hills and valleys of the country, yet great changes must have subsequently taken place in the physical geography of the district; and Sir C. Lyell states that there is reason to conclude that, since the deposition of this fluviatile loam, all the land between Switzerland and Holland has suffered a subsidence and a subsequent elevation, to the amount of many hundred feet.

58. OTHER TERTIARY STRATA OF EUROPE, NORTH AMERICA, &c.—It has already been mentioned, that strata referable to the period comprehended between the uppermost secondary formations and the human epoch occur throughout Europe; presenting in some instances well-defined groups, with marked boundaries, and in others vast areas over which the deposits are irregularly spread. The geographical relations of the tertiary strata to the existing lands and seas is an interesting subject of inquiry, but on which my limits forbid me to enter.† I may, however, observe, that Europe must have possessed many of its most striking physical characters at the commencement of the eocene period; and that its present configuration has been produced by the conjoint effect of successive mutations in the relative level of land and water during the deposition of the marine and fresh-water strata reviewed in this discourse.

* Principles of Geology, Edit. 5, vol. iv. p. 33.

† Lyell's Principles of Geology should be consulted.

In North America the researches of Morton, Vanuxem, Lyell, Rogers, Tuomey, and other observers have shown that in the territories of the United States eocene and miocene deposits extend over a great part of Maryland, along the coast of New York and New England, and occur in New Jersey, Delaware, Long Island, &c. The tertiary beds of Maryland consist of limestone, clay, sand, and gravel, and abound in the usual eocene shells; some of which are identical with European tertiary species of *turritella*, *venericardia*, *fusus*, *ancilla*, &c. The remains of a large cetaceous animal (named *Zeuglodon*, from its deeply cleft or "yoked" teeth) are found in great numbers in some of the American eocene deposits.*

Infusorial marls of Virginia. The towns of Richmond and Petersburg in Virginia are built on strata of siliceous marls, which extend over considerable tracts of country, and have an aggregate thickness of more than twenty feet. These marls, whose organic composition was first detected by Professor W. Rogers, are of the older tertiary (miocene or eocene) formations. The investigations of Dr. Bailey have shown, that these earths are almost wholly made up of the siliceous microphytes, or frustules of Diatomaceæ,† termed *Navicula*, *Galionella*, *Actinocyclus*, *Coscinodiscus*, &c.: the latter especially predominate, two or three species forming a large proportion of this aggregation of minute organisms. The *Coscinodisci* ‡ (or sieve-like discs) are elegant saucer-shaped shields, elaborately ornamented with hexagonal spots disposed in curves, and resembling the engine-turned sculpturing on a watch; they vary in size from 1-100th to 1-1000th of an inch in diameter. If but a few grains of the Richmond earth are prepared for the microscope, all the varieties above specified are generally displayed, so largely is this marl composed of the flinty valves of the

* See Medals of Creation, vol. ii. p. 780.

† Ibid. vol. i. p. 88, 337. ‡ Ibid. vol. i. p. 98.

frustules of minute vegetable organisms; in fact, very few inorganic particles enter into its composition.*

59. ALTERED TERTIARY STRATA OF THE ANDES. — But, striking as are the proofs already adduced of elevations and subsidences, and other effects of volcanic agency during the tertiary period, they sink into comparative insignificance, when contrasted with the enormous changes which have taken place in the great mountain-chains of South America, during the same geological epoch. From the observations of Mr. Charles Darwin, we learn that an extensive tertiary system, analogous to that of Europe, skirts both flanks of the crystalline rocks which form the southern chain of the Andes; the latter having suffered a certain degree of elevation before the deposition of the former. These strata, which are of great thickness and extent, are separable into two groups; the lowermost beds, like those of Auvergne, repeatedly alternate with lavas, and thus denote the commencement of the eruptions of the ancient craters. Over these are accumulations of porphyritic pebbles, covered, at elevations of many hundred feet, by beds of shells of recent species; and the sides of the mountains appear like a succession of sea-beaches, which have been slowly and tranquilly lifted up. The altered character of the tertiary deposits within the influence of the igneous products,—the conversion of beds of loose pebbles into solid, compact rocks,—and the occurrence of metalliferous veins in strata of comparatively modern origin,—are facts so powerfully exemplifying the geological principles enunciated in the former lectures, that, though this discourse has extended to a great length, I cannot omit Mr. Darwin's interesting description of these phenomena, as originally communicated in letters to Professor Henslow, of Cambridge, dated Valparaiso, 1835.

* See in Medals of Creation, vol. i. p. 97.

"You will have heard an account of the dreadful earthquake of the 20th February. I wish some of the geologists who think the earthquakes of these times are trifling could see the way in which the solid rocks are shivered. In the town there is not one house habitable; the ruins remind me of the drawings of the desolated eastern cities. We were at Valdivia at the time, and felt the shock very severely. The sensation was like that of skating over very thin ice, that is, distinct undulations were perceptible. The whole scene of Concepcion and Talcuana is one of the most interesting spectacles we have beheld since leaving England. . . . . I was much pleased at Chiloe by finding a *thick bed of recent oyster-shells, &c., capping the tertiary plain*, out of which grew large forest-trees. I can prove that both sides of the Andes have risen in this recent period to a considerable height. Here the shells were 350 feet above the sea. . . . . On the bare sides of the Cordilleras, the complicated dykes and wedges of variously coloured rocks are seen traversing, in every possible form and shape, the same formation, which by their intersections prove a succession of violences. The stratification in all the mountains is beautifully distinct, and, owing to a variety in their colouring, can be seen at great distances. [Porphyritic conglomerates, resting on granite, form the principal masses.] I cannot imagine any part of the world presenting a more extraordinary scene of the breaking up of the crust of the globe, than these central peaks of the Andes. . . . . The strata in the highest pinnacles are almost universally inclined at an angle from 70° to 80°. I cannot tell you how much I enjoyed some of these views; it is worth coming from England once, to feel at once such intense delight. At an elevation of from ten to twelve thousand feet there is a transparency in the air, and a confusion of distances, and a sort of stillness, which give the sensation of being in another world. . . . . The formation which I call porphyritic conglomerates is the most important and most developed in Chili. From a great number of sections, I find it to be a true coarse conglomerate or breccia, which passes by every step in slow gradations into a fine claystone-porphyry; *the pebbles and cement becoming porphyritic, till at last all is blended in one compact rock.* The porphyries are excessively abundant in this chain, and I feel sure that at least four-fifths of them have been thus produced from sedimentary beds *in situ.* . . . . . The Uspellata range is geologically, although only six or seven thousand feet high, a continuation of the grand eastern chain. It has its nucleus of granite, consisting of grand beds of various crystalline rocks, which I can feel no doubt are subaqueous lavas, alternating with sandstone, conglomerates, and white aluminous beds (like decomposed felspar) with many other curious varieties of sedimentary deposits. . . . . In an escarpment of compact greenish sandstone, *I found a small*

wood of petrified trees in a vertical position; or rather, the strata were inclined about 20° or 30° to one point, and the trees 70° to the opposite; that is, they were before the tilt truly vertical. The sandstone consists of many horizontal layers. . . . . Eleven of the trees are perfectly silicified, and resemble the dicotyledonous wood which I found at Chiloe and Concepcion; the others, thirty to forty in number, I only know to be trees from the analogy of form and position; they consist of snow-white columns of coarsely crystallized carbonate of lime. . . . . They are all close together, within one hundred yards, and about the same level; nowhere else could I find any. It cannot be doubted that the layers of fine sandstone have quietly been deposited between a clump of trees, which were fixed by their roots. *The sandstone rests on lava; is covered by a great bed, apparently about one thousand feet thick, of black augitic lava; and over this there are at least five grand alternations of such rocks and aqueous sedimentary deposits, amounting in thickness to several thousand feet.* . . . . . According to my view of these phenomena, the granite, which forms peaks of a height probably of 14,000 feet, has been fluid in the tertiary period; strata of that period have been altered by its heat and are traversed by dykes from the mass; are now inclined at high angles, and form regular or complicated anticlinal lines. *To complete this climax, these same sedimentary strata and lavas are traversed by very numerous true metallic veins of iron, copper, arsenic, silver, and gold; and these can be traced to the underlying granite. A gold-mine has been worked close to the clump of silicified trees.*"

60. TERTIARY SALIFEROUS DEPOSIT.—Not only coal, but even extensive beds of rock-salt occur in the tertiary system. The celebrated salt-mines of Galicia, of which M. Boué * has given an interesting description, belong to this epoch. The deposit is nearly 3000 yards long, 1066 broad, and 280 yards deep. The upper part of the mine consists of green salt, with nodules of gypsum in marl. The salt contains in some places lignite, bituminous wood, and shells. In the lower division are beds of arenaceous marls, with lignite, impressions of plants, and veins of salt; coarse sandstone, with vegetable remains; aluminous and gypseous shale, and indurated calcareous marl, with sulphur, salt, and gypsum. Amongst the vegetable remains found in the salt-rock of

* Journal de Géologie

Wieliczka, are the wood and cones of three or more species of *Pinus;* besides the fruits of two species of *Juglans* (Walnut).

61. RETROSPECT.—So numerous and varied have been the phenomena presented to our notice, that a comprehensive retrospect is necessary, in order to obtain a correct idea of the highly interesting deductions resulting from this general survey of the tertiary formations.

In the newer tertiary, or pliocene, including the mammalian epoch of the last lecture, the fossil remains in the alluvial deposits afford incontestable proof that the mammoth, mastodon, hippopotamus, gigantic deer, and other colossal animals of extinct species and genera, together with birds, reptiles, and carnivora, inhabited such districts of our continents as were then above the waters; while the older tertiary, or eocene, enclose the bones of land-animals, principally pachyderms, approximating to certain races that now exist in the torrid zone, but belonging to extinct genera. The seas and lakes of that remote epoch occupied areas the greater part of which is now dry land; and rocks and mountains, hills and valleys, streams and rivers, diversified the surface of countries which have since been either destroyed or entirely changed; and the past existence of which is only revealed by the deposits that were accumulated in the lakes and deltas, by streams and rivers. The ocean abounded in mollusca, crustacea, and fishes, of which a large proportion is referable to extinct species. Crocodiles, turtles, birds, and insects were contemporary with the palæotheria and anoplotheria; and animal organization, however varied in certain types, presented the same general characters as in modern times; the extinction of species and genera being then, as now, in constant activity. The vegetable world also contained the same great divisions; there were forests of oak, elm, and beech, of firs, pines, and other coniferous trees, palms, tree-ferns, and the principal groups of our modern

floras; while the water, both salt and fresh, teemed with the few and simple forms of vegetable structure peculiar to that element.

The state of the inorganic world is not less manifest: the abrasion of the land by streams and rivers,—the destruction of the sea-shores by the waves, and the formation of beach and shingle,—the desolation inflicted by volcanic eruptions,—all these operations were then, as now, in activity. The bed of an ancient sea, containing myriads of the remains of fishes, crustaceans, and shells, now forms the site of the capital of Great Britain; and accumulations of tropical fruits and plants, with remains of crocodiles, serpents, turtles, and birds, drifted by ancient currents from other climes, constitute the shores and islands of the estuary of the Thames; while the sediments of inland seas, lakes, and gulfs, teeming with the skeletons of beings which are blotted out from the face of the earth, compose the country around the metropolis of France.

Notwithstanding that the changes in the relative level of the land and sea during this epoch were numerous and extensive, one region still preserves traces of its original physical geography; and, though the earthquake has rent its mountains to their very centre,—though hundreds of volcanos have again and again spread desolation over the land,—and inundations and mountain-torrents have excavated valleys, and chequered the plains with ravines and water-courses,—yet the grand primeval features of that country remain; and we can trace the boundaries of its ancient lakes, and the successive changes which its surface has undergone from the first outbreak of its volcanos to the commencement of the present state of repose. The lowermost lacustrine deposits in Auvergne, which are spread over the foundation-rocks of gneiss and granite unmixed with igneous productions, mark the period antecedent to the volcanic era; while the intrusions of lava and scoriæ in the

superincumbent strata denote the first eruptions of Mont Dome. The succeeding period of tranquillity is recorded in characters alike intelligible. The slow deposition of calcareous mud—the incrustation of successive generations of aquatic insects, crustacea, mollusca, and infusoria—the imbedding of the bones of mammalia, birds, and reptiles—the accumulation of lignite and other vegetable matter—are data from which we may restore the ancient country of Central France.

It was a region encircled by a chain of granitic mountains, watered by numerous streams and rivulets, and possessing lakes of vast extent. Its soil was covered with luxuriant vegetation, and peopled by palæotheria, anoplotheria, and other terrestrial mammalia; the crocodile and turtle found shelter in its marshes and rivers; aquatic birds frequented its fens, and sported over the surface of its lakes; while myriads of insects swarmed in the air, and passed through their wonderful metamorphoses in the waters. In a neighbouring region,* herds of ruminants and other herbivora, of species and genera now no more, with birds and reptiles, were the undisturbed occupants of a country abounding in palms and tree-ferns, and having rivers and lakes, with gulfs which teemed with the inhabitants of the sea; but to this district the fiery torrents of the volcano did not extend. But to return to Auvergne; a change came over the scene; —violent eruptions burst forth from craters long silent,—the whole country was laid desolate,—its living population was swept away,—all was one vast waste, and sterility succeeded to the former luxuriance of life and beauty. Ages rolled by;—the mists of the mountains and the rains produced new springs, torrents, and rivers,—a fertile soil gradually accumulated over the cooled lava-currents and the beds of scoriæ, to which the sediments of the ancient lakes, borne down by the streams, largely contributed. Another vegeta-

* That of the Paris area.

tion sprang up,—the mammoth and mastodon, with enormous deer and oxen, now quietly browsed in the verdant plains; —other changes succeeded,—those colossal forms of life in their turn passed away, and at length the earlier races of mankind took possession of a country, which had once more become a scene of fertility and repose.

To those who have favoured me with their attention through this discourse, it cannot be necessary to aver, that the successive changes in organic and inorganic nature thus rapidly portrayed are supported by proofs so incontrovertible, and traced in characters so intelligible, as to constitute a body of evidence with which no human testimony can compete. It is true that the time required for this succession of events must have extended over an immense period; but time and change are great only in relation to the beings which note them, and every step we take in geology shows the folly and presumption of attempting to measure the operations of nature by our own brief span. "There are no minds," says Mr. Scrope, "that would for one moment doubt that the God of Nature has existed *from all eternity;* but there are many who would reject as preposterous, the idea of tracing back the history of *His works* a million of years. Yet what is a million, or a million of millions of years, when compared to eternity?"*

Germany presents us with an interesting series of analogous changes, effected in a later era. The outburst of the now extinct volcanos of the Rhine, the accumulation of fluviatile silt over the plains, and the subsequent elevation of the whole country, show that these physical mutations were not confined to a single region or period.

In the Andes, the enormous disruptions and elevations of the most ancient as well as modern deposits teach us, that, through a long lapse of ages, the volcanic fires of South America have acted with intense energy; and yet more,

* Geology of Central France.

that the melting and transmutation of loose materials into compact rocks, the conversion of incoherent strata into solid stone, and even the sublimation of gold and other metals into fissures and veins, are phenomena which have taken place since our seas were peopled by mollusca of existing species. The importance of these extraordinary and interesting facts will be rendered more obvious in a subsequent lecture.

62. CONCLUDING REMARKS.—In conclusion, it will be useful to inquire, even though some repetition may be incurred, what are the legitimate inferences from the facts that have been placed before us, as to the condition of our globe and its inhabitants during the tertiary epoch? Was there, as some have supposed, an essential difference in the constitution of the earth?—was its surface more covered with lakes and marshes than now?—and did animal life more abound in those types which are suitable to a lacustrine condition?—or have such conclusions been drawn from a partial view of the phenomena, and do the facts only warrant the inference, that certain regions which are now dry land, were in ancient times submerged beneath the sea, or covered by vast lakes; and that there may have existed contemporaneously as great an extent of dry land as at present, in areas now buried beneath the ocean?—In the fossilized remains of the population of the tertiary lands and waters, we find all the grand types of the existing faunas,—terrestrial, lacustrine, and marine mammalia,—herbivora and carnivora,—birds of every order, and of numerous species and genera,—reptiles, fishes, crustacea, insects, mollusks, zoophytes, and even those living atoms, the foraminifera,—in short, all the leading divisions and subdivisions of the animal creation. In the vegetable world the same general analogy is maintained; and, as all these varied forms of being required corresponding physical conditions, we have at once conclusive evidence that the general constitution of

the earth and the correlation between the organic and inorganic kingdoms of nature during the tertiary epoch were essentially the same as at present. Dry-land and water, continents and islands, existed then, as now,—their geographical distribution may have varied,—the temperature in certain latitudes may have been much higher,—fertile countries may have occupied areas now covered by water, and marshes and fens may have prevailed in regions now arid and waste; but the same agents of destruction and of renovation were then in as constant activity as at present. It is true that immense numbers of large mammalia lie buried in regions where such creatures could not now find subsistence, and in latitudes where the climate is at this time unsuitable to such forms of organization. But some of these apparent anomalies may be explained by the fact, that the alluvial beds in which these remains occur cannot have been the sites of the dry land on which these extinct beings existed; they are the sediments of ancient lakes, the deltas of former rivers, the estuaries of seas,—they are formed of the detritus of the land transported from a distance, and spread over areas then submerged beneath the waters. If the Gulf-stream annually strews the shores of the Hebrides with the fruits of torrid climes, the currents of the ancient seas must have produced analogous results; and, in our attempts to interpret past changes, it must not be forgotten that they have most probably been produced by causes similar to those which are still in action. I do not question the assumption, that some of the countries containing these fossil remains may have enjoyed a milder climate during the tertiary ages than at present; or that in still more ancient periods there may not have prevailed a much higher temperature; but it appears to me, that the variation of climate which a change in the relative distribution of the land and water would occasion, as suggested by Sir C. Lyell,*

* Principles of Geology.

may account for all the phenomena of this nature, which our examination of the tertiary formations has revealed.

The occurrence of groups of animals of the same families in certain districts is in strict conformity with the distribution of living species in regions not under the control of man. Thus, when ancient France presented a system of lakes, animals fitted for such physical conditions found there the means of subsistence,—when the vast plains and forests of America were adapted for colossal mammalia, there the mastodon and the mammoth obtained food and shelter,—and when the former continent of Europe swarmed with herbivora, the carnivorous tribes, as the great felines and the hyena, obtained the support which their habits and economy required.

One striking feature in the events that have passed in review before us is the immense scale on which the extinction of species and genera seems to have been effected: but it must be remembered, that our observations have extended over periods of vast duration, and that we have been contemplating the aggregate effects of a law which even in modern times has produced, and is still producing, great and important modifications in the system of animated nature. In our attempts to penetrate the mystery which veils the early scenes of the earth's physical history, by a reference to the effects of the laws which now govern the organic and inorganic kingdoms of nature, the caution of the illustrious philosopher Playfair should be ever present to our minds:—"If existing causes appear to be inadequate to the effects produced, it may be only that, in respect to man, their movements are too slow to be perceived. The utmost portion of the progress to which human experience can extend is evanescent in comparison of the whole, and must be regarded as the momentary increment of a vast progression, circumscribed by no other limits than the duration of the world. Time performs the office of integrating the infinite

small parts of which the progression is made up,—it collects them into one scene, and produces from them an amount far greater than any that can be assigned from human observation." *

Thus the tertiary epoch displays to us a state of the globe replete with life: the physical constitution of the earth's surface, and the condition of the land and sea, being adapted to the habits and economy of beings of the same types of organization as those which exist at the present time. In the most ancient periods certain forms of life prevailed and gradually became extinct, and were succeeded by others which in their turn also passed away; and, in tracing the varying types of vitality from the earliest ages, we perceive a gradual approach to the present condition of organic nature, in the contemporaneous existence of extinct forms with those which now exist; the grand line of separation between the present and the past being the creation of the human race. From that era, in proportion as Man has extended his dominion over the earth, many races of animals have been either exterminated or modified by his caprices or necessities; and it cannot be doubted, that in the lapse of a few thousand years vast changes will be effected by human agency alone in the geographical distribution and relative numerical proportion of many of the existing genera and species of animals.

* Illustrations of the Huttonian Theory.

LECTURE IV.

Part I.

1. Introductory. 2. Formations of the Secondary Epoch. 3. Cretaceous Formation. 4. White Chalk and the Chalk-Downs. 5. Flint nodules and veins. 6. Organic remains in flint. 7. Animalcules in flint. 8. Spiniferites. 9. Middle and Lower groups of the cretaceous strata. 10. Folkstone Cliffs. 11. Cretaceous strata of Maestricht. 12. The Mosasaurus. 13. Cretaceous deposits of other countries. 14. Organic remains of the Chalk Formation. 15. Fossil plants of the Chalk. 16. Zoophytes of the Chalk. 17. Animalcules of the Chalk. 18. Chalk Rosalinæ. 19. Chalk-detritus at Charing. 20. Crinoidea of the Chalk. 21. Star-fish. 22. Echinites. 23. Shells of the Chalk. 24. Cephalopoda. 25. The Nautilus. 26. Ammonites. 27. Turrilites and Hamites. 28. The Belemnite. 29. Crustaceans of the Chalk. 30. Entomostraca of the Chalk. 31. Fishes of the Chalk. 32. Scales of Fishes. 33. Teeth of Sharks. 34. Hypsodon and other fishes. 35. The Osmeroides. 36. Macropoma. 37. Beryx, and other fishes of the Chalk. 38. Reptiles of the Chalk. 39. Fossil Turtles. 40. Summary.

1. Introductory.—The knowledge we have acquired from our investigation of the phenomena described in the previous lectures will materially facilitate our geological progress, by enabling us to comprehend the former effects of those physical agencies by which the surface of the earth has been perpetually renovated, and maintained in a suitable condition for the existence of successive races of animated beings.

The elevation of the beds of seas and rivers, and their conversion into fertile countries,—the submergence of islands and continents beneath the waters of the ocean,—the rapid formation of conglomerates from shells and corals on the sea-shore,—the accumulation of beach and gravel, and the inhumation of animals and vegetables,—the slow deposition of sediments by lakes and rivers,—the imbedding of innumerable generations of insects, and the formation of limestone from their almost invisible skeletons,—the con-

struction of solid stone out of fragments of bones and rocks shivered by earthquakes,—the ingulfing, in estuaries and inland seas, of land-animals, birds, and reptiles,—the conversion of organic and inorganic substances into rock, from the infiltration of flint and lime by thermal waters,—the transmutation of submerged swamps and forests into coal and lignite,—the destructive and the conservative effects of volcanic eruptions,—the consolidation of sand, gravel, and clay into indurated masses by heat,—and the production of metalliferous veins,—all these phenomena have passed in review before us, although our inquiries have extended through periods which, however vast and remote in relation to the records of our race, are but brief and modern in the physical history of our planet.

The geological events previously described, though forming a connected series, may be divided into periods, each of which is marked by certain zoological characters; namely, 1st, The *Modern*, or *Human Epoch;* 2nd, The *Elephantine*, characterized by the preponderance of large pachydermata; 3rd, The *Palæotherian*, in which animals allied to the tapirs prevailed, and the European area presented a system of gulfs and lakes.

2. FORMATIONS OF THE SECONDARY EPOCH. — We proceed to the consideration of an antecedent epoch, — that which comprehends the Secondary Formations. Hitherto our attention has been principally directed to deposits confined within comparatively limited areas, as the basins of lakes, gulfs, estuaries, and inland seas; and the superficial accumulations of drifted materials, produced by the action of torrents, rivers, icebergs, glaciers, inundations, &c. We have now arrived on the shores of that ocean of whose deposits the existing islands and continents are principally composed; the deep beds of the ancient seas are spread before us, and the relics of innumerable myriads of beings which lived and died in their waters, and became entombed in their

profound abysses, remain, like the mummies of ancient Egypt, the silent yet eloquent teachers of their own eventful history.

A reference to the Tabular Synopsis (p. 200) will show that the secondary formations constitute the following principal subdivisions; viz. the *Cretaceous*, *Wealden* and *Purbeck*, *Oolitic* and *Liassic*, *Triassic*, *Permian*, *Carboniferous*, *Devonian*, and *Silurian* and *Cambrian* systems, each containing littoral and oceanic deposits; sandstones having been formed amidst the agitated waters of the sea-shores; clays in tranquil bays and gulfs; and limestones in deep water. I purpose, in the present discourse, to explain the geological characters of the first two of the series, namely, the CHALK and the WEALDEN.* The former is composed of strata that have been accumulated in the depths of a sea of great extent; the latter, of the sediments of a vast delta; the one affording a striking illustration of the nature of *oceanic*, and the other of *fluviatile* deposits. As both the Chalk and the Wealden are fully developed in the south-east of England, the phenomena about to be described may be readily examined, and collections of the peculiar fossils of these formations obtained, with but little trouble.†

3. THE CRETACEOUS OR CHALK FORMATION.‡—The near-

* The Purbeck beds will be included under this heading. The term Wealden is derived from the German *Wald*, signifying a Wood or Forest The *Weald* of Sussex was formerly an impenetrable forest, called *Anderida* by the Romans, and *Andreadswald* by the Saxons.

† The Author's extensive collection of the Fossils of the south-east of England was purchased some years since by the Trustees of the British Museum. A brief compendium of its contents was previously published by the Sussex Royal Institution, under the title of "*Descriptive Catalogue of the Mantellian Museum at Brighton*," 8vo, Brighton, 1836: fifth edition. Most of the more important specimens have been fully noticed in "*Petrifactions and their Teachings, or the Fossils of the British Museum*," 8vo, London, Bohn, 1851.

‡ For a masterly and elaborate treatise on the Cretaceous series, and

ly pure, soft, white limestone called *Chalk* is known to every one; but in the nomenclature of geology, the term is applied to a group of deposits very dissimilar in lithological composition, but agreeing in the nature of the organic remains which they contain, and evidently referable to the same geological epoch. The series essentially consists of green and ferruginous sands, clays, marls, and grey and white limestones, abounding in marine remains. With this explanation it will be convenient to employ the term in its extended sense. The Chalk-formation comprises the following principal subdivisions:—

1. Gosau beds * (in the Eastern Alps).
2. Maestricht beds † (in the Netherlands).
3. Chalk with flints. (Upper chalk of England.)
4. Grey chalk, or chalk without flints. } (Lower Chalk of England.)
5. Chalk-marl. }
6. Upper Greensand. (Firestone.)
7. Gault.
8. { Rusty and green sands. / Kentish Rag. / Atherfield Beds. } Lower Greensand.

The Chalk either underlies or forms the surface (more or less obscured by gravel and drift) of the south-eastern counties of England, with the exception of the triangular area known as the Weald of Kent and Sussex (see map). The hills bordering the Weald are composed of the more or less upturned edges of the cretaceous strata, which are there easily studied in the innumerable quarries and sand-pits ex-

on the labours of geologists in connection with this formation, the reader is referred to M. D'Archiac's Progrès de la Géologie, vols. iv. and v.

* The Gosau and Maestricht beds are here enumerated as indicating the existence, on the Continent, of true cretaceous beds decidedly of later age than the English so-called "Upper Chalk."

† See further on, p. 318.

posing their structure. These strata are also readily traced at their outcrop along the north-western edge of the chalk area of the south-east of England, from Yorkshire, through Norfolk, Cambridgeshire, Beds, Bucks, Berks, and Wilts, to Dorset and South Devon.

A limited area of chalk and greensand (the latter termed "mulatto") occurs in Antrim, Ireland, where the former has been much disturbed and altered by basalts and other igneous rocks, evidently of post-cretaceous date. Patches of chalk-flints and greensand, probably the relics of strata once existing there, have been found in Aberdeenshire.*

On the Continent the cretaceous deposits are largely developed; and, taken as a whole, the chalk-formation may be described as extending over a great part of the south and east of England, Denmark, Sweden, France, Germany, Greece, European and Asiatic Russia, and Eastern Asia; it occurs also in Southern India (Pondicherry) † and in Southern Africa (near Natal); ‡ and it is extensively distributed in North and South America. Over this vast extent, the organic remains present certain general characters, sufficiently precise to determine the nature of the deposits. Whether imbedded in pure white limestone, coarse sandstone, blue clay, loose sand, or compact rock, the fossils consist, for the most part, of species of the same genera of shells, corals, sponges, echinites, belemnites, ammonites, fishes, reptiles, and other marine animal exuviæ; also wood and plants. The white chalk extends along a great part of the Dorset, Hampshire, Sussex, and Kentish coasts; the precipitous headland of Beachy Head and the cliffs at Dover are well known; these natural sections exhibit the manner in which

* See Mr. Ferguson's paper in the Proceedings of the Glasgow Phil. Soc. vol. iii. p. 44; and Mr. Salter's Geol. Journ. vol. xiii. p. 83.

† Geol. Transact. 2nd Ser. vol. vii. p. 85.

‡ Geol. Journ. vol. xi. p. 453.

the beds have been displaced, and thrown into various inclined positions.*

Along the southern coast of the Isle of Wight, the entire series comprised in the Cretaceous series of England is exposed to view; and the characters and relations of the various deposits may be studied with facility, either on the south-eastern or south-western coasts of the "beautiful island." The white chalk strata, thrown into a nearly vertical position, and boldly displayed, on the east at *Culver Cliff*, and on the west at the *Needles*, traverse the island from east to west; being covered on the north by tertiary deposits. In Sandown Bay, the strata have an anticlinal † position, and on each side of the axis of elevation the several members of the Chalk series, namely the lower greensand, gault, upper greensand, chalk-marl, and chalk, appear in their natural order of succession. A similar section is seen in Compton Bay; while along the Undercliff, fallen masses of the upper beds, intermingled with detritus, form the ruinous cliffs of that picturesque tract; and beyond, at Black-gang and Atherfield, the lower greensand series constitutes the line of coast; the Wealden forming the cliffs in Brixton and Brook bays. The details of this interesting district are described in the Geological Excursions round the Isle of Wight and along the adjacent Coast of Dorsetshire.‡

4. WHITE CHALK, AND THE CHALK-DOWNS.—The features of a chalk district are very peculiar, when the surface has not been broken up for tillage, or is not concealed by

* See The Fossils of the South Downs, or Illustrations of the Geology of Sussex; Geology of the South-east of England; Geology of the Isle of Wight.

† *Anticlinal:* a term applied to strata which incline or dip from a central axis, like the ridge-tiles on the roof of a house.

‡ 1 vol. 8vo, with numerous illustrations, sections, map, &c. 3rd Edit. Bohn, London, 1854.

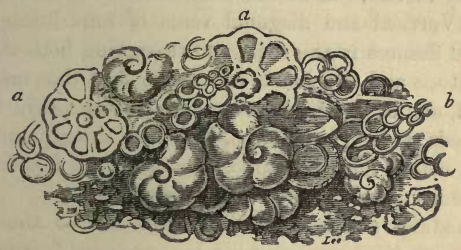
woods and forests. The rounded summits of the hills clothed with short verdant turf,—the smooth undulated outlines of the Downs, unbroken save by the sepulchral mounds of the early inhabitants of the country,—the coombes and furrows, ramifying and extending into the deep valleys which abruptly terminate at the base of the hills, and appear like dried-up channels of rivulets and streams, though free from all traces of alluvial debris, thus bearing the impress of physical operations of which the agents that produced them have long since passed away,—are phenomena that must be familiar to every one who has travelled over the downs of the south-east of England. These features are restricted to the hilly districts where the *white chalk* forms the subsoil, and have resulted from the peculiar nature of the sedimentary detritus of which the strata comprised in the upper division of the cretaceous system are composed. For where the lower group of clays, marls, sands, and sandstones approach the surface and form the subsoil, the country is broken and diversified, and the landscape presents a striking contrast with the scenery of the Downs.

The upper division of the cretaceous system is composed of beds of a very peculiar white limestone, varying in thickness from a few inches to several feet. In the *White Chalk* (Upper Chalk of England *) there are numerous parallel rows of siliceous nodules, termed flints, disposed in irregular distances from each other; and in some places sheets or seams of flint are intercalated between the chalk strata, and extend over considerable areas. The chalk is also traversed by vertical and diagonal veins of flint. The only metallic substances are oxide of manganese, in the state of dendriti-

* The chalk of the neighbourhood of Norwich appears, from its fossil contents, and other characters, to be the youngest of the cretaceous beds of Britain; but even this is much older than the chalk of the Netherlands, some cretaceous deposits in Denmark, and the *calcaire pisolitique* near Paris.

cal or arborescent markings, and oxide and sulphide of iron. Iron-pyrites occasionally constitutes the casts of shells, echini, &c., the surface of the mineral retaining sharp imprints of the structural characters of the original.

The white chalk is composed of lime and carbonic acid; and a microscopical analysis proves it to be a mere aggregation of, 1. microscopic shells and moss-corals, so minute that upwards of a million of the former are contained in a cubic inch of the rock; 2. fragments of the above and of larger shells, especially the cell-prisms of the *Inocerami;* 3. still finer particles which, under a powerful microscope, appear to be the detritus of similar structures, and not a chemical precipitate.



LIGN. 55.—CHALK-DUST; highly magnified, seen partly by transmitted and partly by reflected light.
a, a Rosalinæ. *b.* Textulariæ.
(From "Thoughts on a Pebble.")

The appearance of a few atoms of chalk-dust, under a highly magnifying power, is shown in this figure (*Lign.* 55). These organisms are the calcareous cases and shells of the animalcules termed *Foraminifera,** which swarm in inconceivable numbers in our present seas, and are daily and hourly contributing to the amount of sediment now accumulating in the bed of the ocean.

* Medals of Creation, vol. i. p. 339.

5. FLINT NODULES AND VEINS.—The *flints* (as the siliceous nodules are generally termed) occur in horizontal rows or layers, generally parallel with the lines of stratification of the chalk, but placed at unequal distances from each other. They are of all sizes, from that of a small nut to masses several feet in circumference. But besides these parallel beds of nodular flints, there are sheets of flint intercalated between the chalk strata, and covering areas often many miles in extent. These continuous layers are termed tabular flint; they are seldom more than two or three inches in thickness, and veins and threads of silex frequently ramify from them into the fissures of the surrounding chalk. This tabular flint is generally solid throughout, but sometimes encloses a layer of chalky matter, full of the usual minute organisms of the chalk. Vertical and diagonal veins of flint filling up crevices and fissures in the rock, and traversing both the strata of limestone and any sheets of tabular flint that may be interposed, are of common occurrence; these prove that the lower beds were consolidated, and had subsequently been fissured, before the superimposed strata were deposited, and the siliceous matter found its way into them.

The nodules and veins of flint * that are so abundant in the upper chalk have probably been produced by the agency of heated waters holding silex in solution, and depositing it when poured into chalk-sea. The perfect fluidity of the siliceous matter before its consolidation is proved not only by the sharp moulds and impressions of shells, &c. retained by the flints, but also by the presence of numerous organic bodies in the substance of the nodular masses, and the silicified condition of the sponges and other zoophytes which swarm in some of the cretaceous strata. Though silex, or

* M. D'Archiac, in the 5th vol. of his admirable and highly useful work on the Progress of Geology (Progrès de la Géologie), gives an excellent résumé of the opinions of the authors who have treated of the origin of flints in chalk, and gives also a list of the works on this subject.

the earth of flint, is insoluble in boiling water, its solution, as we have previously stated (p. 93), readily takes place in vapour heated to a temperature above that of fused cast-iron (p. 100); and similar effects are being produced at the present moment by the thermal waters of active volcanos (p. 98). The temperature to which water may be raised depends on the presence or absence of air; for it has been proved by direct experiment that water deprived of air may be heated to 275° of Fahrenheit, under the ordinary pressure of the atmosphere, without exhibiting any symptoms of ebullition. The solvent power of water on rocks containing silex may, therefore, be fully adequate to produce all the phenomena presented by the siliceous nodules, veins, dikes, &c. of the chalk-formation; and our chalk-flints may possibly have originated from the quartz of granitic and other plutonic rocks, dissolved in heated water, and erupted into the basin of the ancient chalk-ocean.

There are other observers, however, who are inclined to believe that the flints on the chalk, as also in the Portland oolite, and other calcareous deposits, owe their origin to the *sponges*, of which such frequent traces are recognisable in connection with the flint. Mr. J. S. Bowerbank * advocates this origin for every kind of flint nodule and vein in the chalk, and has amassed a large collection of recent sponges illustrative of the growth of the porifera over and within shells, sea-urchins, crustaceans, sponges, corals, and other organisms, as well as over inorganic substances and in clefts of rock. How or why the silex, thus considered as representing the *sponges*, should have invested or replaced organic bodies and the porifera in particular, is still left unaccounted for.

Lastly, Prof. Ehrenberg has suggested that the flints may be due to the chemical segregation of silex derived from the siliceous remains of diatomaceæ, polycystineæ, &c.

* Geol. Transact. vol. vi. p. 181. British Assoc. Reports, 1856.

6. ORGANIC REMAINS IN FLINT.—In many instances the organic remains in chalk-flints are simply incrusted by silex: such is the state of numerous sponges * which are, as it were, invested by the flint, and have their pores and tubes filled by the same material; the original tissue having disappeared, or been replaced by soft, ferruginous, earthy matter. In other examples the sponge has been apparently enveloped by a mass of liquid silex, and has subsequently perished; in this manner have been formed those hollow nodules, which on being broken present a cavity containing only a little white powder, or some fragments of silicified sponge: while in other instances the cavity is lined with quartz or chalcedony. It frequently happens that only part of the zoophyte is permeated by silex, while the other portion is in the state of a friable calcareous earth imbedded in the chalk.

Sponges and other organic bodies often form the nuclei of flint nodules, and the original substance of the fossil is generally silicified, and the most delicate internal structure preserved. In other instances the enclosed organisms have undergone no change, but appear as if immersed and preserved in a semi-transparent medium; such is the state in which foraminifera, moss-corals, &c. often occur.

But there are innumerable flint nodules which exhibit no traces of spongeous structure, and veins, dikes, and sheets of tabular flint that may be regarded as pure, and free from organic remains, excepting such as must inevitably have become entangled and embedded in a stream of mineral matter flowing over a sea-bottom, and into its fissures and cavities. Wood which has been perforated by lithodomi, and silicified, is not scarce. Bones of reptiles and fishes are often impacted in a mass of flint; but in only one instance have I observed that the silex has permeated the osseous structure.

* See Medals of Creation, vol. i. chap. vii.

In the London Geological Journal of September, 1846, Mr. Charlesworth described an interesting specimen of a part of a jaw of a cretaceous reptile allied to Mosasaurus, in which the pulp-cavities of the teeth are partially filled with black flint, without any accompanying silicification of the surrounding bony tissue; and he supposes that a fluid holding silex in solution, or the silex in a viscid state, must have reached the cavity by traversing the vascular passages in the bone of the jaw. The same memoir contains a short résumé of the opinions of Werner, Buckland, Turner, and Ehrenberg, on the origin and formation of the flints in Chalk.

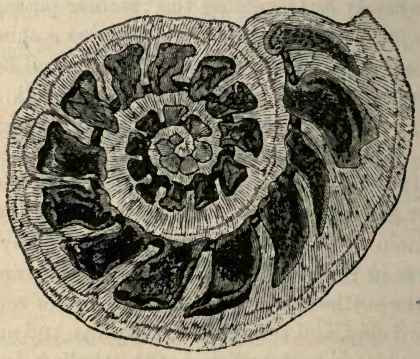
7. ANIMALCULES IN FLINT.—For the most part, the minute shells in the chalk and flint are filled with amorphous mineral matter; but in many examples, as I have ascertained by direct experiment,* the soft parts or body of the animalcule remain in the shell; sometimes completely silicified, but in others in the state of *dried animal membrane*, like the ink-bag of the cuttle-fish in lias, the soft parts of cephalopoda in the Oxford clay, and the capsule of the eye and membranes of the air-bladder in certain fishes of the chalk.† In the flints such specimens are by no means rare, and, from the semi-transparency of that mineral, are easily detected under the microscope. The annexed figure (*Lign.* 56) represents the body of a *Rosalina* in its shell; the original is in flint and invisible to the naked eye, but under a good microscope its structure is beautifully defined; the folds of the membrane

* See my observations "On the Fossil Remains of the soft parts of Foraminifera discovered in the chalk and flint of the south-east of England." Philosophical Transactions, 1846, p. 465.

† I would refer the general reader who is not conversant with the various conditions in which the remains of vegetables and animals occur in the mineral kingdom, according to the circumstances under which they were originally imbedded, and the chemical changes they may have subsequently undergone, to my remarks "*On the Nature of Fossils or Organic Remains*," Medals of Creation, vol. i. chap. iii. See also "*Instructions for the collecting of Fossils*," vol. ii. p. 831.

in the cells being as obvious as in a specimen obtained from the sea.

The shells of the Rosalinæ and Textulariæ in the chalk * also contain the desiccated soft parts of the animalcules unmineralized; and by dissolving the chalk and shells in



LIGN. 56.—THE SHELL OF A ROSALINA, CONTAINING THE FOSSILIZED BODY OF THE ANIMAL; IN FLINT. Seen by transmitted light. *(Highly magnified).*

weak hydrochloric acid, and immersing the residue in a transparent medium (*Canada balsam*), the tissues are as distinctly seen as in the recent state. I shall again refer to

* The soft parts of Foraminifera are also obtainable from the gault, by careful manipulation. and from the Kimmeridge clay, in which the Rev. Mr. Reade obtained them several years since.

† Specimens of the Foraminifera, Spiniferites, and other minute fossil organisms of the chalk and flint may be obtained of *Mr. Topping*, the well-known microscopic artist, No. 1, York Place, Pentonville Hill; Mr. Norman, 14, Fountain Place, City Road; and of Mr. Tennant, 149, Strand. See Medals of Creation, vol. i. pp. 65, 371, and vol. ii. p. 639, for *Instructions how to prepare Fossils for the Microscope.*

this subject when treating of the organic remains of the cretaceous system. In this place, however, I would call your attention to an exquisite example of the preservation of the soft parts of an animalcule in flint. The fossil here delineated (*Lign.* 57) was discovered by the Rev. J. B. Reade, a gentleman well known for his accurate microscopic investigations. It is apparently a polyp-cell with a portion of the animal protruded, and the whole enveloped in once fluid silex: with the exception of the tentacula, which appear either to have perished, or to have collapsed so as not to be distinguishable, the form and structure of the original are admirably preserved.

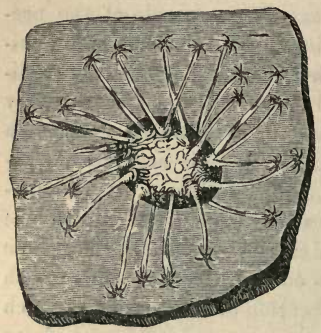
LIGN. 57.
CORAL-POLYP (?) in flint, *(magnified 500 diameters). Seen by transmitted light.*

8. SPINIFERITES (*Xanthidium*, Ehrenberg; *Asteridium*, Smith).—Microscopic spherical bodies very similar to those frustules of *Desmidiaceæ*,* which Ehrenberg has named *Xanthidia*, are so abundant in the flints, that I must briefly notice them in this place. These minute fossils occur both in the chalk and the flint; and, though frequently silicified, have been detected unmineralized in the chalk, and as flexible as the soft parts of the foraminifera.†

* For a notice of the Desmidiaceæ and other minute infusorial organisms formerly regarded as animals, but now grouped with the vegetables, see Medals of Creation, vol. i. p. 91, 239.

† The Spiniferites were first discovered in this state by Mr. H. Deane, Microscopical Society's Transactions, 1846. A specimen from the chalk, also obtained by Mr. Deane, is figured in the Phil. Trans. 1846, Pl. xxi. fig. i.

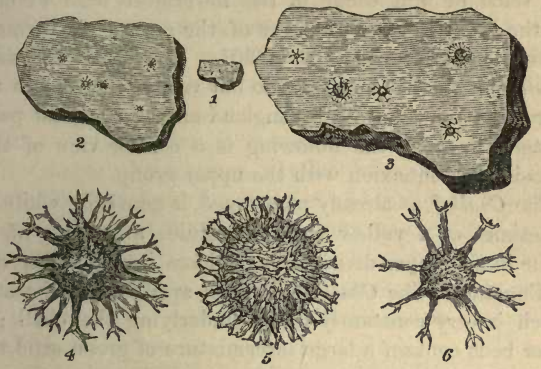
The little spherical fossil bodies under notice are probably the spores of algæ; they are membranous and hollow; beset with spines or tubular processes, which, in many species, are fimbriated at the extremities, and vary considerably in number and length. Some specimens (*Lign.* 58) have these appendages very long, and their extremities patulous and fimbriated. In a rare species (discovered by Mr. Reginald N. Mantell), the spines are short, equal, and relatively thick (*Lign.* 59, *fig.* 5); in others they are intermediate in length, proportions, and number (as in *Lign.* 59, *fig.* 4, 6). The manner in which these bodies occur in the flint is shown in the example figured in *Lign.* 59; which is a thin chip containing five Spiniferites, that was broken off at random from a nodule. The specimen is represented of the natural size in *fig.* 1; slightly magnified as seen by transmitted light in *fig.* 2; and under a higher power in *fig.* 3; the fragment having been previously rendered as transparent as glass by immersion in Canada balsam. *Figs.* 4, 5, 6, represent the three best-defined specimens highly magnified.



LIGN. 58.—SPINIFERITES PALMATUS.
Magnified 500 diameters.
(Drawn by Rev. J. B. Reade.)

The Rev. Mr. Reade first noticed the Spiniferites of the English chalk, and figured several forms, which he found in flint, in the Annals of Natural History, 1838, vol. ii. Mr. H. H. White subsequently illustrated a greater variety of fossil forms of these problematical bodies in vol. i. of the Transactions of the Microscopical Society. Mr. H. Deane, in the second volume of these Transactions, supplied additional materials for the study of the Spiniferites of the Chalk, and Mr. S. J. Wilkinson contri-

buted to the same volume a paper on fossil and recent Xanthidia, the latter having been obtained from New York, the Mediterranean, and in the Thames at Greenhithe. In the 3rd volume of the Microscopical Society's Transactions, 1852, p. 165 and 168, Mr. Shadbolt has published some interesting remarks and very instructive drawings of these Xanthi-



LIGN. 59.—SPINIFERITES IN FLINT.

(Seen by transmitted light.)

Fig. 1. A thin transparent chip of flint: natural size.
2. The same magnified, viewed by transmitted light.
3. More highly magnified.
4. *Spiniferites ramosus*; one of the animalculites seen in the previous figures, magnified 300 diameters.
5. *Spiniferites Reginaldi*; another from the same group.
6. A variety of *Spiniferites ramosus*.

dium-like bodies, which he regards as the "sporangia of some of the filamentous fresh-water Algæ." The Rev. W. Smith, treating of these spiny globules (which he terms *Asteridia*) in the Quarterly Journal of Microscopical Science, vol. i. p. 63, observes that he has found them not only in the filamentary Algæ (as Mr. Shadbolt had), but also in Desmidiaceæ, and occasionally in Diatomaceæ; he could not, however, regard them as Sporangia, but looked upon them as abnormal growths of the nuclei, or as parasitical. Whatever their true character as organisms may be, the Spiniferites or Asteridia clearly have some close relation to the Confervaceæ and other Microphytes; and the numerous specimens found in the chalk are probably referable to marine plants of the same low order of Algæ.

9. MIDDLE AND LOWER GROUPS OF THE CHALK FORMATION.—Beneath the Chalk-with-flints is a series of strata of equal thickness, termed the Grey Chalk and Chalk-marl, in which no flints are met with in England, except in a few localities; in some places on the Continent, however, nodules and veins of flint occur in the lowermost beds of chalk. Of the lower inferior members of the cretaceous formation there are some remarks at p. 301. The *Upper Greensand*, *Gault*, and *Lower Greensand* do not very much vary in their characters and relations in England and over a great part of western Europe: the following is a concise view of these deposits, in connexion with the upper group.

The *Chalk*,* as already mentioned, is generally white, but sometimes of a yellow colour; nodules and veins of flint occur in the upper division, but seldom in the lower chalk of England. The *Chalk-marl* is an argillaceous limestone, which is very constantly found underlying the chalk; the lower beds contain a large intermixture of green sand,† and

* Thin seams of a greenish-coloured marl intervene between some of the white chalk strata. A portion of this earth from Southerhan pit, near Lewes, analyzed by my friend, Mr. Gladstone, of Stockwell, gave the following results:

Carbonate of lime	26·66
Lime	4·35
Alumina	2·31
Peroxide of iron	1·49
Sulphate of magnesia	2·14
Organic matter	5·14
Insoluble in acids—probably silica	55·21
Loss	2·20

† These green grains,—composed of silicate of iron, and forming so frequent an ingredient in rocks of all ages, from the silurian sands of the north-west of Russia, to the oolitic, cretaceous, and tertiary deposits, —are especially interesting since Ehrenberg and Bailey have demonstrated the frequent occurrence of recognisable casts of shells of the minute Foraminifera as green or colourless grains amongst these greensands, and apparently sometimes forming a considerable proportion of the whole. Mr. Bailey has lately noticed a similar formation of green-

pass into green and greyish sands, or coarse calcareous sandstone with green grains (the "firestone" of Reigate), which constitute the *Upper Greensand.* This is represented in Cambridgeshire by a thin band of phosphatic nodules and organic remains (fully representing the *fauna*, or group of animals, of the cretaceous sea in this district) imbedded in a marly greensand; and appears to be absent still further northward. In Wilts and Dorset, however, it is considerably developed; sometimes to a thickness of more than 100 feet. The sponge-gravels of Faringdon, and the cherty sandstone of Blackdown in Devonshire, have been referred to this member of the series. It has been suggested, however, that the latter was deposited in the shallower waters of the chalk-sea, whilst the gault was being accumulated in the deeper water; and that the former belong to the Lower Greensand. In Yorkshire and Norfolk a bed of hard red chalk underlies the chalk-marl, to the exclusion, apparently, of the Upper Greensand.

The *Gault* is a stiff, dark-blue clay, abounding in shells, which, as in most argillaceous beds, retain their pearly coatings unimpaired in lustre. It is sometimes seamed with red marl, and occasionally contains nodules of clay-stone. Green sand is not uncommon in it, both as intercalated bands, and disseminated, especially towards the base, where it frequently abounds with gritty nodules enclosing broken casts of ammonites, fragments of wood, and other organic remains.

The *Lower Greensand* is a group of sands, sandstones limestones, and clays; with beds of chert and fuller's earth in some localities. The upper portion of the Lower Greensand in the south-east of England consists of ferruginous and white sands,* passing towards the south into sandstones

sand in a recent state (Gulf of Mexico). See Annals Nat. Hist., 1856, No. 107, p. 425; and Berlin Transact. 1855.

* The white sand is well shown close to the little quaint old town of

and grits, with much green sand, and full of sponges and shells of a large *Gryphæa*. These underlie the gault at Folkstone, and pass downwards into argillaceous beds, also full of green sand. The lower part consists, 1st, of sandstone, and a highly fossiliferous grey limestone (known as "Kentish Rag"), with some chert and abundance of the usual green grains: 2nd, of dark-coloured clays and sandrock, termed the Atherfield beds.* In other parts of England the Lower Greensand is represented by ferruginous and green sands, with occasional beds of sandy stone or grit. At Nutfield, near Reigate, this series has yielded a large supply of fuller's earth for many years.

These various strata can be studied with facility on the southern coasts of the Isle of Wight;† at the northern end of Swanage Bay (where, however, they are much squeezed); and along some parts of the Dorsetshire coast; also at Southbourn, on the Sussex coast, where the Gault, with the Upper and Lower Greensands, emerge from beneath the white chalk on the north of the South Downs; and on the coast of Kent, where the same group rises from under the chalk on the south side of the North Downs. The Hunstanton cliffs and the coast north of Flamborough Head afford sections of the more northern equivalents of these beds.

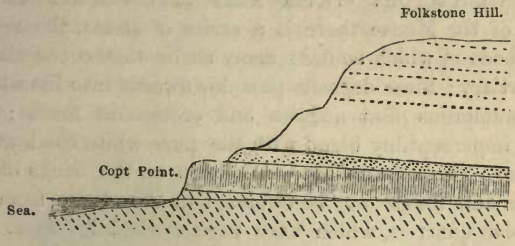
10. FOLKSTONE CLIFFS.—The relative position of the cretaceous beds is well displayed at Copt Point, near Folkstone. The Upper Greensand (which is very thin in this neighbourhood) appears as a terrace inland, coming out be-

Aylesford on the Medway, and is used for glass-making. The Lower Greensand near Aylesbury, Bucks, and at a few other places, also affords white glass-sand.

* For detailed accounts of this series, see Dr. Fitton's Memoirs in the Transact. Geol. Soc., 2nd Ser., vol. iv.; Journ. Geol. Soc., vol. iii. p. 284; and Geology of the Isle of Wight, p. 164.

† See Geology of the Isle of Wight, for lists and figures of fossils of the cretaceous series of that district.

low the chalk-marl; the Gault constitutes the face of the cliff, and reposes on the Lower Greensand, which forms the base of the cliff (*Lign.* 60). Eastware Bay, near Folkstone, is celebrated for the beauty and variety of the Gault fossils,



LIGN. 60.—DIAGRAM-SECTION OF THE STRATA AT EASTWARE BAY, NEAR FOLKSTONE.

1. The Upper Chalk. 2. Lower Chalk, and Chalk-marl. 3. Upper Greensand. 4. Gault. 5. Lower Greensand.

which are constantly being washed out of the cliff by the action of the sea.

This series may be traced with more or less distinctness around the denuded area of the Wealden. The lowermost member, the Lower Greensand, rises into more importance towards the west; and in Surrey, Hampshire, and western Sussex, forms a line of bold hills, which runs parallel with the chalk-downs, and rivals them in altitude; a valley of gault generally intervenes between the sand and chalk, as at Reigate. Along the Kentish coast the three natural subdivisions of the Lower Greensand are clearly defined. The upper member, or Shanklin sand, is chiefly made up of ferruginous sands, with ironstone and concretions of chert, and dark sandy clays in the lower part. The middle group is marked by the prevalence of green and grey sand, with bands of calcareous sandstone and cherty limestone, called Kentish Rag. The lowermost, or Atherfield series, consists principally of sandy argillaceous beds, with layers of concretionary

limestone, containing numerous peculiar fossils. The Shanklin and Atherfield deposits are so named from localities in the Isle of Wight where they are developed in great thickness and extent.*

11. CRETACEOUS STRATA NEAR MAESTRICHT.—In the valley of the Meuse there is a series of strata, the uppermost beds of which contain many shells that occur also in the tertiary; these deposits pass downwards into limestones with numerous flint nodules and cretaceous fossils; and these imperceptibly blend with the pure white chalk at the bottom. These strata are well shown on the banks of the Meuse, and fossils may be obtained in abundance from the extensive quarries, which have been worked for ages. St. Peter's Mountain, in which these excavations are situated, is a cape or headland between the Meuse and the Jaar, formed by the extremity of a range of hills which bounds the western side of the river-valley. The mountain commences at the distance of a mile south of Maestricht, and extends in a direction towards Liege for about three leagues; it presents an almost perpendicular escarpment towards the Meuse. A section of the hill affords the following succession of strata:—

1. Calcareous freestone, and beds of loosely aggregated sand, of a yellow fawn-colour, abounding in fossils. Numerous layers of flint occur throughout the entire series, having the usual characters of the siliceous nodules of the chalk.

2. Chalk, very hard and gritty.

3. Lowermost: White chalk, with layers of flint nodules.

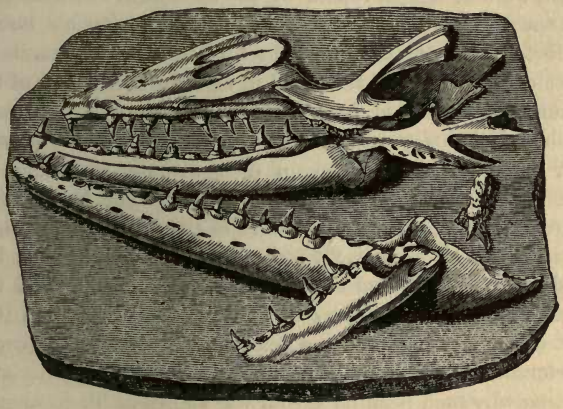
The Maestricht freestone is so extremely soft in the quarry that it may easily be cut with a knife, but it hardens and becomes of a lighter colour by exposure to the air.†

* See Geology of the Isle of Wight for details; chap. vi.

† The avidity of collectors has induced the quarrymen to practise an ingenious fraud upon strangers: teeth and bones of the horse, boar, &c., are carefully imbedded in blocks of the limestone while it is soft; and

The beds of limestone have a total thickness of about 500 feet. Excavations have for centuries been carried on in the strata of freestone, and, from the immense quantities of stone removed, extensive caverns and galleries now traverse the heart of the mountain. Shells, corals, crustacea, teeth of fishes, and other marine remains occur in profusion; with wood perforated by boring mollusks, and the bones of a large and very remarkable reptile.*

12. THE MOSASAURUS; OR FOSSIL REPTILE OF THE MEUSE.—The occasional discovery of bones and teeth of an



LIGN. 61.—REMAINS OF THE JAWS OF THE MOSASAURUS.
Discovered at Maestricht, by M. Hoffmann, in 1770; now in the Museum at Paris.
(Four and a half feet by two and a half.)

unknown animal in the limestone had long since directed the attention of naturalists to the quarries of St. Peter's

when the stone becomes hard, the specimens are offered for sale as genuine fossils from the quarries; the deception may be detected by immersing them in water.

* See Hist. Nat. de la Montagne de St. Pierre, by Faujas St. Fond, 1 vol. 4to (1799), with fine engravings and numerous figures of the fossils that have been discovered in the quarries of St. Peter's Mountain.

Mountain. In 1770 M. Hoffmann, who was forming a collection of organic remains, had the good fortune to discover a specimen which has conferred additional interest on this locality. Some workmen, on blasting the rock in one of the caverns of the interior of the mountain, perceived, to their astonishment, the jaws of an enormous animal attached to the roof of the chasm. The discovery was immediately made known to M. Hoffmann, who repaired to the spot, and for weeks presided over the arduous task of separating from the rock the mass of stone containing these remains. His labours were at length repaid by the successful extrication of the specimen, which he conveyed in triumph to his house. Unfortunately, the Canon of the Cathedral which stands on the mountain claimed the fossil in right of being lord of the manor, and succeeded, by a vexatious and expensive lawsuit, in obtaining this precious relic. It remained in his possession for years, and Hoffmann died without regaining his treasure, or receiving any compensation. The French Revolution broke out, and the armies of the Republic advanced to the gates of Maestricht; the town was bombarded, but by desire of the committee of *savans*, who accompanied the French troops, the artillery was not allowed to play on that part of the city in which the celebrated fossil was known to be contained. In the mean while the Canon, shrewdly suspecting why such peculiar favour was shown to his residence, concealed the specimen in a secret vault; but, when the city was taken, the French authorities compelled him to give up his ill-gotten prize, which was immediately transmitted to the *Jardin des Plantes*, at Paris, where it still forms one of the most striking objects in that magnificent collection.

A model of this specimen is in the British Museum, and another in the Museum of the Geological Society: it consists of the jaws, teeth, palate-bones, vertebræ, and *os quadratum*, a bone possessed by some reptiles, and in which

the auditory cells are contained.* There are some fine portions of jaws, with teeth, and some vertebræ of the Mosasaurus in the British Museum. The original was a reptile, holding an intermediate place between the *Monitor* and *Iguana*, about twenty-five feet long; its tail appears to have been of such construction as to have rendered it a powerful oar, enabling the animal to stem the waves of the ocean, of which Cuvier * supposes it to have been an inhabitant.

In the English chalk a few remains of this reptile, or of a species very closely allied, have been met with. I collected three vertebræ from the upper chalk near Lewes, many years since;† and have also obtained a caudal vertebra from Kemptown, near Brighton; the latter is partially invested with flint, which has consolidated around it without obscuring its essential characters.‡ Mosasauroid teeth occur in the cretaceous deposits of Galicia, and have been met with in the chalk of Kent and of Essex.§ Some are apparently indistinguishable from those of the large Mosasaurus (*M. Hofmanni*), others belong to the *M. gracilis*, and others to *Leiodon anceps* (*M. stenodon*, Charlesworth).

Remains of Mosasauri and closely allied genera occur in the cretaceous deposits of Upper Missouri and New Jersey,‖ U. S., and afford additional proof of the extension of the waters of the chalk-ocean over the area now occupied by the Atlantic and part of the dry land of North America.

* See Fossils of the British Museum, p. 196. The Mosasaurus, represented by a fine restoration of its head, takes its place amongst the primeval monsters in the Crystal Palace gardens.

† See Ossements Fossiles, vol. v. p. 326, &c.

‡ Geology of the South-East of England, p. 146; Fossils of the South Downs, pl. 33 and 41.

§ Medals, vol. ii. p. 707; Dixon's Fossils, Sussex, pl. 37 and 39; and Owen's Monog. Reptiles of the Chalk, 1851. Mr. Fitch's collection at Norwich contains some mosasauroid teeth from the Norfolk chalk.

‖ Dr. Gibbs, Smithsonian Contributions, vol. ii.; Dr. Morton's Synopsis Org. Rem. U. S.; and Prof. Rogers, Quart. Geol. Journ. vol. v.

13. CRETACEOUS STRATA OF OTHER COUNTRIES.—In the north of France the same characters predominate; but in the south, the group is more or less calcareous throughout; and the lower division, which is the representative of our greensands and clays, consists of calcareous beds, with white limestone and tufaceous marlstone.

In Central and Eastern Germany the entire system is more siliceous, calcareous matter being very sparingly distributed. In Saxony it consists of siliceous sandstone,—conglomerates, chert, and ferruginous sand and sandstone,—calcareous grit containing the well-known gault-shell, *Inoceramus concentricus*,—and calcareous rock with hamites, scaphites, terebratulæ, and plagiostoma; the uppermost strata yielding a siliceous building-stone.

In Russia the white chalk is finely developed in the southern steppes of the Don Cossacks;* and Artesian wells have been carried to a depth of 630 feet through these strata, without indicating any change of rock. The chalk at Uspensk lies in hollows of the carboniferous system, and contains many well-known English cretaceous shells. In the royal collection at Warsaw are echinoderms and shells from the Polish chalk, identical with our common species; even the *Choanites Kœnigi* occurs in the flints, as in those of the South Downs.† Sir R. Murchison observed true chalk on the banks of the river Ural, the extreme boundary of Russia in Europe. On the Volga the white chalk passes, through a group of clay-stones and shales, into tertiary eocene strata. The surface of the chalk of Russia is nowhere eroded as in Western Europe.

In North America, the cretaceous deposits of Nebraska appear to contain fossils that are representatives of those of

* Russia and the Ural, vol. i. p. 265. All the remarks relating to the Geology of Russia are derived from this work of Sir R. I. Murchison and his companions.

† Medals, vol. i. p. 233.

the middle and upper members of the British series, a few species only being identical with ours. The chalk strata of New Jersey,* that intervene between the Alleghany mountains and the Atlantic, lithologically resemble the sandy and argillaceous beds of our gault and greensand; but contain few fossils identical with those of Europe. The overlying tertiaries consist of marly clays and variously coloured sands, with green particles, as in the bottom of the mottled clays near Reading. Such is, for the most part, the character of the series in New Jersey: and further south, in Maryland and Virginia, the eocene strata are as full of green particles as the cretaceous, and can only be distinguished by their fossils and geological position.†

14. Organic remains of the Chalk formation.‡—I

* The cretaceous strata of New Jersey appear to agree in chronological relations with the upper cretaceous deposits of Europe, including the gault, chalk-marl, chalk, and the Maestricht beds. From the comparison of the cretaceous shells of New Jersey with those of the chalk series of Europe, it may be observed that the correspondence is not small, when we reflect that the part of the United States where these strata occur is between 3000 and 4000 miles distant from the chalk of central and northern Europe, and that there is a difference of ten degrees in the latitude of the places compared on opposite sides of the Atlantic.—*Lyell.*

These strata also contain remains of sharks and of Mosasaurus, and bones of a large crocodilian reptile of the procœlian division, i. e. with the anterior surface of the vertebræ concave, and the posterior convex, as in existing crocodiles.

† See Sir C. Lyell's Remarks on the Cretaceous Strata of New Jersey, in his Travels in North America. Also Prof. Rogers's Address to the Association of American Geologists. 1844.

‡ For illustrations of Cretaceous Fossils, the reader is referred to the Author's Fossils of the South Downs; the Palæontographical Monographs, for 1849—56, for the Reptiles, Corals, Entomostracans, Brachiopods, Barnacles, and Cephalopods of the English chalk formation; to the Decades of the Geological Survey, for the Echinoderms and some Fishes; to Dixon's Fossils of Sussex, &c., for numerous and beautiful illustrations of a great proportion of the organic remains of the English chalk; to the Pictorial Atlas, for several good figures of cretaceous fossils; to Sowerby's Mineral Conchology, for correct figures of many of the typical

would remind the reader, that the numerous groups of strata comprised in the cretaceous system are to be regarded as an ancient ocean-bed;—a vast accumulation of sedimentary deposits, more or less consolidated by subsequent chemical changes, that was formed in the profound depths of the sea, in periods of unfathomable antiquity. This mass is made up of inorganic and organic materials: the former consist of the debris of the cliffs and shores which encompassed the ancient sea,—of the spoils of islands and continents brought into the ocean by floods and currents of fresh water,—and of mineral deposits thrown down from chemical solutions; the *organic substances* are the durable remains of animals and plants which lived and died in the ocean, and of fluviatile and terrestrial species that were transported from the land by rivers and their tributaries. The whole forms such an assemblage of sedimentary deposits as would probably be presented to observation, if a mass of the bed of the Atlantic, 2000 feet in thickness, were elevated above

fossils; to Portlock's Geological Report on Londonderry, for figures of the cretaceous fossils of Ireland; to Woodward's Geology of Norfolk, for the chalk-fossils from near Norwich; and to Phillip's Illustrations of the Geology of Yorkshire, for the more northern cretaceous fossils. The foreign works on this subject are D'Orbigny's Paléontologie Française, and his Paléont. Universelle; Roemer's Cretaceous Fossils of North Germany; Reuss's Fossils of the Bohemian Chalk-formation; Bronn's Lethæa Geognostica (new edit.); Hisinger and Nilson on Swedish Fossils; numerous papers in the French Geol. Soc. Memoirs, by D'Archiac, Leymerie, &c.; in Haidinger's Abhandlungen, and in the Transactions of the Vienna and other societies, by Reuss, Czjzek, Alth, and others; Bosquet's Memoirs on the Crustaceans and Brachiopods of the Chalk of the Netherlands and Belgium; Faujas de St. Fond's great work on Maestricht; Roemer's work on the Fossils of the Chalk of Texas; Morton's Synopsis of the Organic Remains of the United States; and Hall and Hayden, Description of the Cretaceous Fossils from Nebraska. The Pondicherry fossils are described in the 7th vol. of the Geolog. Transact.; and the Bogota and Natal chalk-fossils, in the Geological Society's Journal, vol. i. p. 174, and vol. xi. p. 453.

the waters, and became dry land; the only essential difference would be in the generic and specific characters of the imbedded animal and vegetable remains.

The fossils of the cretaceous formation are exceedingly numerous, and offer abundant examples of all the usual forms of marine existence except Cetaceans; and even of these one or two relics are said to have been discovered in America.*

Particular genera and species are, however, restricted to certain subdivisions of the system; thus, in the white chalk there are many species of shells that do not occur in either of the other groups. The chalk-marl, upper greensand, and gault also have peculiar fossils, and the lower greensand abounds in shells and zoophytes, that are wanting in the upper series of deposits. The genera and species of the mollusca must therefore have varied during the period of the deposition of the cretaceous beds; some kinds prevailed at the commencement of the formation, and became extinct, or at least no longer inhabited the same parts of the ocean at a subsequent epoch; while other forms appear for the first time, and, in some instances, are continued into the tertiary epoch.†

* Lyell's Manual, 1855, p. 256. Leidy, Philad. Ac. Proc. vi. p. 377.

† Allusion has already been made to Mr. Prestwich's remarks on this subject in his paper in the Geological Society's Journal, vol. x. p. 449. The following observations by Messrs. Meek and Hayden (Proceedings of the Philadelphia Academy, 1856, vol. viii. p. 63), on fossils from Nebraska, have much importance. "It is worthy of note," say they, "that some of the species contained in the collection from the most recent cretaceous beds of the upper Missouri country appear referable to genera which, according to high European authority, date no farther back than the true chalk, while many of them are closely analogous to tertiary forms; so close indeed, that had they not been found associated in the same beds with Ammonites, Scaphites, and other genera everywhere regarded as having become extinct at the close of the cretaceous epoch, we should have considered them tertiary species. If these beds really are equivalent to any portion of the greensand of English geologists, it is a curious fact that we should find mingled together in them upper cretaceous and

The state of preservation in which the fossils occur varies according to the lithological composition of the strata. The shells, corals, echinites, &c. of the white chalk, are generally transmuted into carbonate of lime having a spathose structure; their cavities are commonly filled with chalk, flint, or sulphide of iron; in many instances they are hollow, and lined with crystals of carbonate of lime. The soft sponges are often silicified, and there is scarcely a flint nodule in which their remains may not be traced. The bones of the reptiles and fishes, and the coverings of the crustaceans, are in a friable state, and stained with sulphide of iron. The teeth and scales of the fishes possess a high polish, and are more or less permeated by ferruginous infiltrations. Wood occurs in the state of lignite in the clays and sands, and in brown friable masses in the chalk, which quickly decompose upon exposure to the air; but, when enveloped in flint, the structure is silicified, and well preserved;* like the fossil wood of the tertiary deposits, it has evidently been drifted, and is perforated by teredines and other boring animals; the fissures are often filled with brilliant pyrites.

The *Upper Greensand* fossils in the cherty sandstones are often silicified; and the whetstone-pits of Devonshire are celebrated for the beauty and variety of the chalcedonic shells, star-fish, &c. with which they abound.

In the *Gault*, the nacreous covering of the shells is commonly preserved, and the ammonites and nautili of Folkstone rival in beauty the shells of the London and Barton clays, and like them are subject to decomposition.

In the sands, limestones, and argillaceous strata of the *Lower Greensand* the shells and other organisms are for the most part well preserved.

tertiary forms, exactly as if they and those of the older tertiary were deposited in the regular order of sequence."

* Medals of Creation, vol. i. p. 174.

The organic remains of the cretaceous system * already known amount to many hundred species. The most striking zoological character is the abundance of sponges, foraminifers, echinoderms, bryozoans, and cephalopods: the last include the shells of several extinct races of cephalopoda, that appear for the last time in the chalk; no traces of their existence having been discovered in the tertiary formation.

15. FOSSIL VEGETABLES.—The marine flora of the chalk, as I have already remarked, offers but little variety: a few species of *Fuci* and *Confervæ* are the only instances that have come under notice. One species of Fucus (*Chondrites Bignoriensis, Lign.* 62) abounds in the chalk-marl of Western Sussex, particularly at Bignor,† where almost every fragment of this rock is marked with its meandering forms. *Confervæ* are occasionally found in the chalk.‡ Plants allied to *Zostera* occur in the chalk of the Isle d'Aix. Drifted wood abounds in the line of junction between the gault and lower greensand.

In the Kentish rag, near Maidstone, there have been discovered fir-cones (*Abietites Benstedi*),§ coniferous wood,‖ petioles of the *Clathraria*,¶ and the stem of a plant apparently allied to *Dracæna*.** The *Coniferæ* (cone-bearing, as the Larch) appear to have constituted the principal feature in the flora of the country whose rivers and streams flowed into that part of the chalk-ocean that is accessible to observation in England. The wood usually met with, whether in the white chalk,

* The reader is referred to the Medals of Creation, for details of the most important organic remains of the chalk; and to Mr. Morris's Catalogue of British Fossils (1854), for lists and references of all the published species.

† See Medals, vol. i. p. 102.

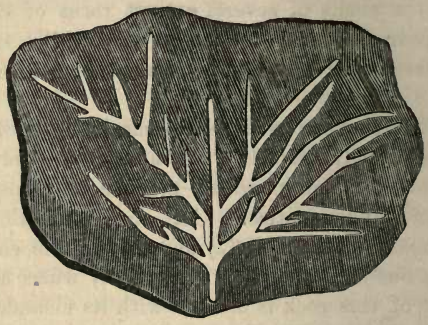
‡ *Confervites Woodwardii.* Medals of Creation, vol. i. p. 101.

§ Geol. Proc. iv. p. 34, and Geol. Journ. ii. p. 52, pl. 2, f. 2.

‖ Medals, vol. i. p. 173. ¶ Medals, vol. i. p. 161.

** Petrifactions, &c. p. 49.

upper greensand, gault, or lower greensand, is coniferous; and most of it possesses the structure of the *Araucaria*, or



LIGN. 62.—FUCOID IN CHALK-MARL; FROM BIGNOR PARK, SUSSEX.
Chondrites Bignoriensis.

Norfolk Island pine. Several pine- or fir-cones have been found, but all of small size.

Of those peculiar coniferous plants, the *Zamia* and *Cycas*, many remains have been collected. A beautiful elongated cone of a Zamia-like plant (*Zamiostrobus*) was obtained some years since, near Willingdon, in Sussex, from a bed at the top of the lower greensand, which abounds in coniferous wood.*

In the chalk-marl at Bonchurch, in the Isle of Wight, a remarkable specimen of the summit of a stem of the *Clathraria*, with the petioles attached, has been discovered; as this plant essentially belongs to the flora of the Wealden, its description will be given in a subsequent section of this discourse.

* It is figured in Geol. Proc. 1843, as *Zamites Sussexiensis*. See Medals of Creation, *Fossil Coniferæ*, vol. i. p. 150 and 174.

A few imperfect specimens of an oval compressed fruit, with numerous seeds, have been found in the chalk near Lewes, and in Kent. This fruit, so far as can be judged from the examples known, appears to have been a compound berry, having, like the mulberry, the seeds imbedded in a soft pulpy mass.*

The Chalk-strata of Bohemia,† of Saxony,‡ of Thuringia (at Blankenburg §), and of Aix-la-Chapelle,‖ have yielded numerous remains of dicotyledonous, monocotyledonous, and cryptogamous plants.¶

16. Fossil Sponges, Zoophytes, and Bryozoa.—The flint nodules of the chalk are seldom destitute of traces of sponges and other kinds of amorphozoa and porifera. The species are numerous in the chalk with flints, and rare in the lower chalk. In the upper greensand several species occur, but only very few that are not also in the chalk. There are none known in the gault, and only one in the lower greensand.

There is a fossil sponge (*Choanites Kœnigi*) which is well known to collectors of Sussex pebbles by the name of *petrified sea-anemone*, from its supposed resemblance to the living Actinia (*pl.* VI. *fig.* 11); but the original was a very different creature. From an extensive suite of specimens, I have ascertained that it was of a pyriform shape with a central opening, from which numerous tubes radiated; and these are oftentimes exquisitely preserved in flint. The external

* This interesting though obscure fruit was named *Carpolithes Smithiæ*, in honour of Mrs. Smith of Tunbridge Wells; a lady of consummate skill in the dissection of chalk-fossils, and most ardent and liberal in the promotion of palæontological science. Medals of Creation, vol. i. p. 202.

† Reuss, Versteiner. Böhmisch. Kreideformation.

‡ Geinitz, Quaderformation.

§ Dunker, Palæographica, vol. iv.

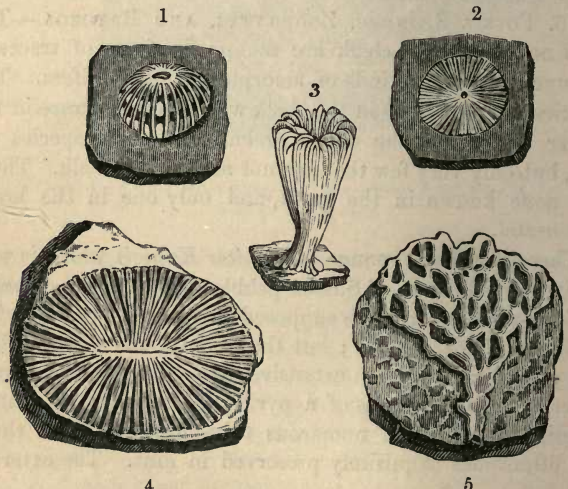
‖ Debey, Quart. Journ. Geol. Soc. vol. vii. part 2, Miscell. p. 109.

¶ Medals of Creation, vol. i. p. 205.

surface frequently exhibits the remains of crucial spines, similar to those possessed by the recent alcyonia.*

Certain zoophytes (*Ventriculites*) are exceedingly numerous in the chalk near Lewes and Brighton; and, being often preserved partly in chalk and partly in flint, give rise to most interesting specimens, which throw light on the segregation of silex in the calcareous sediments of the chalk-ocean.†

In the white chalk, corals are comparatively rare; but the Maestricht beds contain them in great abundance.



LIGN. 63.—CORALS, &C., FROM THE CHALK FORMATION.

Fig. 1. *Trochocyathus Kœnigi* from the gault: the fossil is attached to the clay by the disk, the base lying uppermost and exposed. 2. The upper surface of a *Trochocyathus*, imbedded in gault. 3. *Parasmilia centralis*, from the chalk near Lewes. 4. *Fungia* in limestone, from Maestricht. 5. *Retepora clathrata*, from Maestricht (a Bryozoan).

Several species of a small coral, formerly referred to Caryophyllia, but now known as *Parasmilia* (*Lign.* 63, *fig.* 3),

* Thoughts on a Pebble, pl. 1 and 2; Medals of Creation, vol. i. p. 234; Dixon's Fossils of Sussex, pl. 17; and Pictorial Atlas, pl. 42, 44, and 45.

† Medals of Creation, vol. i. p. 242.

occur not unfrequently in the English chalk, together with about as many more species of other corals, all of small size; a few species of *Trochocyathus* (*Lign.* 63, *figs.* 1, 2) are found in the gault, with two or three other minute corals; and a very few corals occur also in the upper and lower greensands. The absence of the large madrepores and stony corals is a remarkable fact, corroborating the evidence derived from other sources, that the white chalk was deposited in the profound abyss of an ocean; for the economy of the living corals fits them to live only in waters of moderate depths.

There are certain layers of a very friable earthy chalk in the cliffs along the Kentish coast, and especially near Dover, that abound in very delicate and beautiful species of numerous small moss-corals, or bryozoa; as *Actinopora*, *Pustulopora*, *Cellepora*, *Idmonea*, &c. Indeed, throughout the chalk the delicate forms of the above, together with *Eschara*, *Flustra*, *Retepora*, and many other bryozoans,* are very plentiful either loose in the chalk or attached to shells. These are also abundant in the quarries at Faringdon in Berkshire; where, together with sponges, they form a considerable portion of the peculiar crag-like gravels and sands of that place, which have generally been referred to the upper greensand. Bryozoa are very rare in the gault and lower greensand.

17. ANIMALCULITES OR MICROZOA OF THE CHALK.—Under this head I will notice some of the minute organisms of the cretaceous system. The most numerous of these are the chambered, or polythalamous, shells of the foraminifera; as rosalina (p. 310), textularia, &c.†

The *Foraminifera* are marine animals, of low organiza-

* See Medals of Creation, vol. i. p. 271; Dixon's Foss. Sussex, pl. 18 A. The student who wishes to study the Cretaceous Bryozoa must refer to D'Orbigny's Paléontologie Française, and to Hagenow's work on the Bryozoa of the Maestricht and other upper chalk-beds.

† Want of space compels me to refer the reader for many details on this subject to my "*Notes on a Microscopical Examination of Chalk and Flint*," in the Annals of Nat. Hist. 1845, vol. xvi.

tion, and, with but few exceptions, extremely minute; in an ounce of sea-sand between three and four millions have been enumerated. They belong to the class *Rhizopoda*, among which the body consists of a uniform granular jelly (termed *sarcode*), either naked (*Amœba*), or enclosed in a membrane (*Gromia*), or in a calcareous shell (*Foraminifera**), the shell consisting of either one or more cells or chambers. These animals appear, in fact, to be merely morsels of animated jelly (without stomach or nerves) protected by shells; some being simple, the shell having but one cell (such as *Arcella* and *Orbulina*); others having several cells, disposed either in a straight line (*Nodosaria*); or in a discoidal form, like that of the shell of the nautilus, (*Cristallaria*); or on other plans, such as spiral, plaited, &c. (*Rotalia*, *Bulimina*, *Textularia*, &c.). The several forms are distinguished by peculiarities in the aperture, disposition of the septa or partitions, and direction of the spire and volutions. These microzoa swarm in infinite multitudes in the present seas,† and were not less abundant in the ancient ones. We have already spoken (p. 250) of the Nummulites which abounded so extensively in the Eocene period, and which have still living representatives. One of the distinguishing characters of these shells consists in the numerous perforations by which they are traversed, affording exit to minute filaments or processes by which the animal moves, attaches itself, and obtains its nourishment.‡

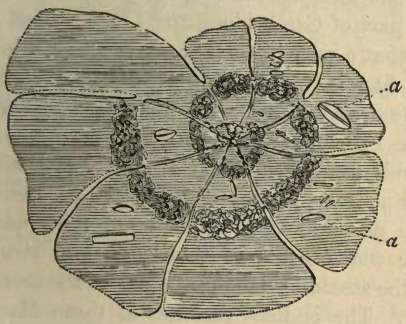
18. CHALK ROSALINÆ.—In the *Rosalinæ* (*Lign.* 55 and 56), which are among the most abundant of cretaceous

* The *Polycystineæ* may be regarded as Rhizopods with siliceous shells or skeletons.

† The deep soundings of the Atlantic have lately shown the bottom of that great ocean to be covered with mud, almost wholly composed of Foraminifera, indistinguishable from those of the chalk forms, together with siliceous Polycystineæ, Sponge-spicula, &c.

‡ See Medals of Creation, vol. i. p. 340 Annals N. H. xix. p. 273.

forms, the body of the animal occupies all the chambers; and the perforations, which are numerous, admit of the exsertion of the soft transparent feelers or pseudo-podia, which are the instruments of motion. The shell, therefore, though presenting the general form of that of the ammonite or nautilus, is essentially different; for in the latter the body of the animal is contained in the outer chamber, and the internal compartments are successively-quitted empty dwellings; whereas in the foraminifer, all the cells are filled by the soft parts of the animalcule contemporaneously. When the shell, which is calcareous, is removed by weak hydrochloric acid, the body is exposed, and is seen to extend to the innermost chamber; and there is a connecting thread which occupies the place of the siphuncle of the nautilus; for the several



LIGN. 64.—The body of a recent foraminiferous animalcule: the shell having been dissolved by acid. From the North Sea, off Cuxhaven. (After Ehrenberg.)

(*Nonionina Germanica*, of Ehrenberg;)

Magnified 200 *diameters.*

In some of the segments (*a*, *a*) Naviculæ and other infusoria are visible.

minute jelly-masses in the cells are united by the narrow neck of sarcode (or the stolon), by which the successive segments of the animal have been produced as gemmules. The

annexed figure, *Lign.* 64, represents a recent foraminifer deprived of its shell.

A comparison of this figure with the specimen in flint, *Lign.* 56, p. 310, will show the close analogy between them.

The soft parts of these foraminifera occur, not only in the flint, but in the white chalk: and by subjecting the latter to the action of dilute hydrochloric acid, the bodies of the rosalinæ, textulariæ, &c. may sometimes be detected as distinct in form as in this recent specimen from the sea (*Lign.* 64). I must refer to my observations on this subject in the Philosophical Transactions (for 1846, part iv. p. 465), for further particulars of this remarkable fact.* Cristellariæ, Rotaliæ, and Textulariæ are some of the prevalent foraminifera in the fossil state; similar forms occur in our seas, and their allies are abundant in the sandy clays which are spread over great part of Cambridgeshire, Lincolnshire, &c.†

Seeing what a very important share these minute organisms have had in building up strata after strata in some parts of the earth's crust, we cannot be surprised that the microscopic Infusoria, the grain-like Foraminifera, and the comparatively massive Nummulites have, by their enormous local accumulations, almost rivalling the productions of the coral-polyp, demanded the attention of the student of geology. The wonders too of their form and structure have called for the assiduous labour of some of the first naturalists of the day. The endless varieties of these Microzoa have exercised the skill and excited the admiration of collector and author. The minute through prolific Ostracodous Crustaceans too, and the humble and wide-spreading Nullipores and Cotallines, have also performed their part in building up

* See above, p. 309; and Medals, vol. i. p. 357.

† See a highly interesting paper on Foraminifera from the Levant, Boston, and Charing, by W. C. Williamson, Esq., in vol. viii. of the Manchester Literary and Philosophical Society, 1847. In the Annals of Nat. Hist. April, 1857, is a critical examination, by MM. Parker and Jones, of numerous recent and fossil Foraminifera.

the rocks of this globe. Of the former there are numerous species, to which we shall make a reference in the sequel.

1

2

LIGN. 65.—SECTIONS OF FORAMINIFERA IN FLINT *(from the South Downs)*.

Fig. 1. Lituola nautiloidea.
2. Placopsilina irregularis.

The chalk-flints often contain, besides the Microzoa mentioned above at page 331, beautiful examples of foraminiferous chambered shells, of a crosier-like form, of which some hundreds of specimens were collected by the late Marquis of Northampton.

The fracture of the flints exposes various sections of these many-chambered shells, according to the positions in which they lie in relation to the exposed surface. The annexed figures (*Lign.* 65) exhibit two longitudinal sections of these foraminifera, both of natural size and enlarged. These shells are also numerous in the chalk.*

The common forms of the English chalk have been found in the cretaceous strata throughout Europe,† Asia, and America.‡

19. CHALK-DETRITUS AT CHARING.—Along the base of the

* Dixon's Fossils of Sussex, pl. 27, figs. 12—14.

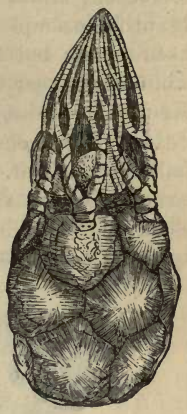
† D'Orbigny, Roemer, Geinitz, and Reuss have figured and described a great many European foraminifera, both cretaceous and tertiary.

‡ Dr. W. Bailey, Professor of Chemistry in the U. S. Military Academy of West Point, New York, has elaborately investigated the fossil infusoria and foraminifera of the United States, and published the result of his researches in the American Journal of Science, and in the "Smithsonian Contributions." See also Geol. Proc. for 1844, p. 310.

North and the South Downs, and elsewhere on the flanks of chalk-hills, and in the valleys at their foot, there frequently occurs a superficial layer of earthy or chalky material, which, on careful manipulation, yields vast quantities of the foraminifera of the chalk in great plenty and variety. Such a storehouse of the remains of the cretaceous microzoa occurs at Charing, between Ashford and Maidstone, at the foot of the North Downs. It was first observed by W. Harris, Esq., of Charing, who has for many years collected its interesting contents,* and distributed them liberally among his scientific friends. A narrow band of whiteish, sandy, tenacious, and calcareous clay is traceable for some miles east and west of Charing, widening out occasionally in the basins or little valleys of the district, and varying in depth from one to several feet. This superficial clay, or "chalk-detritus," appears to have mainly resulted from the decomposing surface of the chalk-marl, the outcrop of which, together with that of the upper greensand (here exceedingly thin), is more or less covered by it. At some places flints from the chalk, and even gravel-flints, are found in the detritus, probably mixed with it at an early period; and, where modern streams or marshes have had much influence on this detrital bed, freshwater and land shells of existing species, seed-vessels, and small bones are found in it. This debris is largely made up of the shells of numerous kinds of foraminifera, spines of sponges, valves of cytherinæ, fragments of bryozoa, and other minute animal remains, with a considerable intermixture of polygonal spicula, resulting from the decomposition of the large fibrous bivalve termed *Inoceramus*, so common in the chalk and chalk-marl.

* Mr. Harris has found that the best plan to procure the shells and other fossils (some of which are of great rarity and beauty) from this clay, is to render it of a creamy consistence with water (by continued agitation in a revolving barrel), and then, washing away the "chalkiness" through a canvas bag, the resulting debris is dried and again carefully washed before sifting and sorting.

20. CRINOIDEA.—The *Crinoidea*, or lily-shaped animals, are but sparingly distributed in the chalk—a circumstance, as you will hereafter find, in striking contrast with the zoological characters of some of the older secondary formations. Stems of *Pentacrinites* * occur both in the chalk and gault; and there are a few species of *Bourguetocrinus*,† which are peculiar to the white chalk.



LIGN. 66.
MARSUPITES MILLERI;
from the chalk, Brighton.

A remarkable cretaceous fossil of this class is the *Marsupite*, which I thus named from its resemblance, when closed, to a purse. The Marsupite (*Lign.* 66) was a crinoideal animal, of a sub-ovate form, having the mouth, which was surrounded by arms, or tentacula, near the centre. The skeleton was composed of crustaceous, hexagonal plates, united by suture; and the arms, which are subdivided into a few branches, were formed of little joints or bones, *ossicula;* the whole was probably invested with a muscular tissue, or membrane. When floating, the creature could spread out its tentacula like a net, and by closing them, seize its prey and convey it to the mouth. This figure (*Lign.* 66) is restored from specimens which separately exhibit the parts here represented.‡

21. STAR-FISHES OF THE CHALK.§—Of the radiated ani-

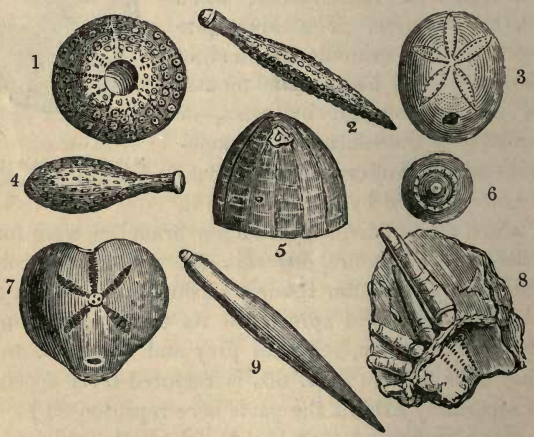
* Dixon's Fossils of Sussex, plate 19.

† Formerly referred to the genus *Apiocrinus;* Medals, vol. i. p. 291; and Dixon's Fossils of Sussex, pl. 20.

‡ There is another species often found with the above, in which the plates are covered with rugous markings; it is the *M. ornatus* of the late Mr. Miller.

§ Medals of Creation, vol. i. p. 301.

mals termed *Asteroidea*, or star-fishes, three genera occur in the English chalk and upper greensand, and others in the cretaceous strata of the continent. In the Sussex chalk, beautiful examples of the *Goniaster*, or cushion-star, have been found; but they are more frequently met with in the white chalk near Gravesend, Northfleet, Purfleet, and other Kentish localities, and occasionally in an almost perfect condition. Specimens of Goniaster are often met with * partly imbedded in flint. Detached ossicula are very abundant in some of the strata; and there are layers of the grey or lower chalk wholly made up of the debris of star-fishes, minute spines of echini, ossicles of pentacrinites, &c.



LIGN. 67.—ECHINITES AND SPINES, FROM THE CHALK.

(Figs. 5, 7, one-third less than the originals.)

Fig. 1. Cidaris. 2, 4, 9. Spines of Cidaris. 3. Nucleolites. 5. Ananchytes ovatus. 6. A tubercle of a Cidaris. 7. Micraster cor-anguinum. 8. Spines and portion of the shell of a Cidaris in flint.

22. ECHINITES.†—Those remarkable animals, the Echini, or sea-urchins, are too well known to require particular

* Dixon's Fossils of Sussex, Plates 21, 22, 23.

† See Medals of Creation, vol. i. chap. xi. p. 311.

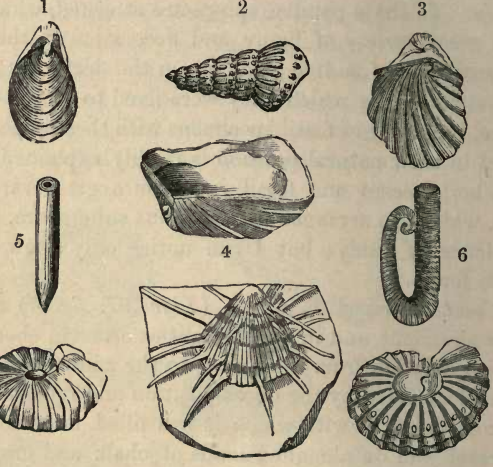
description. Their rounded shell, or case, is composed of polygonal plates, closely fitted to each other; and the surface is divided vertically by bands, like the meridians of a globe, having rows of double perforations. The shell is studded over with papillæ which vary in size, in the different species, from mere granular points to large well-defined tubercles. To these papillæ, spines are attached, which also present great variety of figure and decoration;* these are the instruments of motion; and, as on the death of the animal the tendons by which they were fixed to the shell decompose, the rarity of fossil specimens with these appendages attached in their natural position is readily explained. The Echini, both recent and fossil, comprise a great variety of species, which are arranged in numerous sub-genera, for the convenience of study; but I can notice only a few of the common forms.

The helmet-shaped Echinites (*Lign.* 67, *fig.* 5) are extremely abundant, and in some localities occur in shoals, and in every gradation from the young to the adult state. Siliceous casts, formed by the decomposition and removal of the shell from the flint with which it was filled, are common in flint-gravel and on ploughed lands of chalk and gravel districts. The cordiform variety (*fig.* 7) is very abundant, and gives rise to the heart-shaped flints of our gravel-pits. The elliptical species (*fig.* 3) is not uncommon in the greensands. The turbinated Echinites (*Cidarides*) are beautifully embossed with papillæ: a small species (*fig.* 1) is frequent in the chalk and flints of Kent; the larger varieties possess tubercles surrounded by elegant margins (*fig.* 6), and are otherwise richly ornamented. Some spines are slender, and covered with asperites (*fig.* 2); others almost smooth (*fig.* 9); and others club-shaped (*fig.* 4); it is not often that spines are found in contact with the shell (*fig.* 8); this,

* Medals of Creation, vol. i. p. 319.

however, is occasionally the case, and from the chalk at Gravesend, and other localities in Kent, splendid examples have been obtained; some with groups of large spines attached to the tubercles, as in the living state.*

23. SHELLS OF THE CHALK.—The bivalve shells, or conchifera, of the cretaceous deposits are numerous. Oysters,



LIGN. 68.—SHELLS FROM THE CHALK FORMATION.

Fig. 1. Inoceramus concentricus; from *Gault.*
2. Turrilites costatus; *Chalk-marl.*
3. Inoceramus sulcatus; *Gault.*
4. Inoceramus Lamarckii; *White-chalk.*
5. Belemnites minimus; *Gault.*
6. Hamites; *Gault.*
7. Ammonites Mantelli; *Chalk-marl.*
8. Spondylus spinosus; *White-chalk.*
9. Ammonites Sussexiensis; *Chalk-marl.*

scallops, cockles, and other familiar marine shells abound, but the species differ from the recent. With these known genera are many which, so far as our present knowledge of

* Dixon's Fossils of Sussex, Plates 24 and 25.

the inhabitants of the deep extends, are extinct. The Upper and Lower Chalk are very poor in bivalves, excepting those of the oyster and scallop tribes, and of the Terebratula family. The Gasteropodous molluscs * are very rare in the English chalk and chalk-marl, and not very abundant in the lower beds of the series. The cretaceous deposits of Central Europe and of North America are not unfrequently rich in Gasteropoda.

The Maestricht beds, as before remarked, contain many fossils not found in the other chalk strata. A large *Volute* (*Voluta Faujasii*) occurs in the flint nodules of St. Peter's Mountain, with baculites, ammonites, and other characteristic chalk fossils.

Besides the terebratulæ † and their allies, one of the most numerous of the bivalves is an elegant shell, having one valve covered with long spines (*Lign.* 68, *fig.* 8), the *Spondylus spinosus*. A bivalve with a fibrous structure (*Inoceramus* (*Lign.* 68, *fig.* 4), very brittle, and having a crenulated hinge of a peculiar construction, presents several species; some of which are small and delicately striated, while others are two feet in diameter, and deeply furrowed. The substance of these shells closely resembles in structure that of the recent *pinnæ;* and from its fragility, fragments are very common in chalk,‡ flint, and even in pyrites. The *Gault* contains two species of this genus, which have been found in almost every locality, and appear to be restricted to this division of the chalk series; they are the *Inoceramus concentricus* (*Lign.* 68, *fig.* 1), and *I. sulcatus* (*fig.* 3). A species of Radiolite (*Radiolites Mortoni*) has been met with in the chalk near Lewes in Sussex, and at Barham and Lenham in Kent; and another species is known to occur in the upper

* Dixon's Fossils of Sussex, p. 348, &c.

† Medals of Creation, vol. i. p. 388.

‡ The chalk and chalk-marl are often to a great extent composed of the prismatic cell-fragments of these shells.

greensand; but *Hippurites*, so common in the cretaceous strata of the continent, have not been noticed.*

The bivalve and gasteropod shells of the Chalk, Chalk-marl, Gault, and Greensands amount to more than six hundred species: those of the whet-stone pits of Blackdown, in Devonshire, are completely silicified, and changed into silex or chalcedony.†

24. CEPHALOPODA OF THE CHALK.—The most striking feature in the marine fauna of the chalk, as contrasted with that of the tertiary and modern formations, is the great preponderance of multilocular Cephalopoda.‡ In the tertiary, and existing tropical seas, one genus (the *Nautilus*) occurs abundantly. The beauty, elegant form, and remarkable internal structure of the recent shell have rendered it in all ages an object of admiration; yet an accurate knowledge of the organization of the animal to which it belongs has but recently been obtained. The Nautilus and the allied fossil genera may be regarded as Sepiæ or Cuttle-fishes inhabiting chambered shells, which possess considerable buoyancy, enabling the animals to float at the surface or sink to the depths of the ocean at pleasure.

A few remarks on the recent types of the forms of this group will serve to render the subject intelligible. The *Sepia* or *Cuttle-fish* of our seas is of an oblong form, composed of a jelly-like substance, covered with a tough skin; the mouth, which is central, is furnished with horny mandibles, much resembling the beaks of a parrot. The animal has two large eyes, and eight arms studded with rows of little

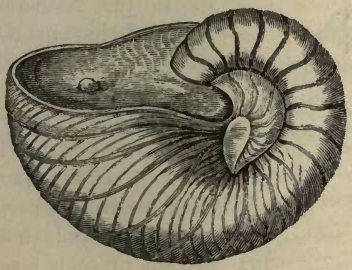
* See Mr. S. P. Woodward's Paper on the Hippuritidæ, Journ. Geol. Soc. vol. xi. p. 40.

† The shells of the cretaceous formation are most fully described and figured in M. D'Orbigny's beautiful work on the fossils of France—Paléontologie Française. Others are elegantly and truthfully portrayed in Dixon's Fossils of Sussex.

‡ See Medals of Creation, vol. ii. p. 447, for an account of the Cephalopoda; and Woodward's Manual of the Mollusca, p. 62, &c.

cups or suckers, which are powerful instruments both of locomotion and prehension. The soft body of the Sepia is supported by a skeleton formed of a single bone or *osselet* of a very curious structure; this calcareous substance, when dried and reduced to powder, is the substance called *pounce*. The Cuttle-fish has a membranous sac which secretes and retains a dark-coloured fluid, resembling ink; this the animal can eject when pursued, and, by thus rendering the water turbid, it escapes from its enemies. From this fluid the colour termed *sepia* was formerly prepared.

25. THE NAUTILUS.—The shell of the Nautilus* consists internally of a series of chambers, pierced through the middle by a siphuncle or tube, which extends to the remotest cell. The body of the animal resembles, in some respects, that of the sepia, and is contained in the outer receptacle of the shell; it maintains a vital connexion with the inner chambers by means of a membranous tube which lines the siphuncle, passing through the internal chambers, which are merely air-cells. If, therefore, you imagine a cuttle-fish placed, with its arms extended, in the outer chamber of a Nautilus-shell, and provided with a tube connected with the siphunculus, but having neither ink-bag nor osselet, these being unnecessary to an animal with the protection and mechanism of a chambered shell, you will have a tolerably correct idea of the recent Nautilus. The Nautilus is essen-



LIGN. 69.—NAUTILUS ELEGANS.
From the Chalk-marl near Lewes.
(One-sixth the natural size.)

* See Medals of Creation, vol. ii. p. 467, for anatomical details, and for references to the memoirs of zoologists on this interesting animal.

tially a ground-dwelling animal, living in deep water, and feeding at the bottom of the sea. Rumphius states that it creeps with the shell above, and that by means of its tentacula it can make quick progress along the ground. There are several species of Nautilus in the chalk, some of which are of large size: a common species from the chalk-marl is figured in *Lign.* 69.

26. THE AMMONITE, OR CORNU-AMMONIS.—The fossils called Ammonites first appear in the lower or earlier beds of the secondary formations, and cease to appear with the termination of the deposits of the secondary period; no traces of their remains having been found in the tertiary or any later deposits, except as drifted fragments. The Ammonite, so called from its supposed resemblance to the horn of Jupiter Ammon, is a fossil chambered shell, coiled up in the form of a disk, bearing a close analogy to the Nautilus, but differing in the situation of the siphuncle, and in the form of the septa by which the interior is divided. In the Nautilus these partitions are entire, and their section presents a series of simple curves; but in the Ammonite they are very sinuous, and the external surface of the casts of the shells commonly exhibits markings resembling the outlines of deeply-fringed foliage; the shell is also generally decorated with flutings, ribs, and tubercles. The siphuncle, which in the Nautilus is central, is situated

LIGN. 70.—AMMONITES VARIANS.
From the Chalk-marl, near Bonchurch.

at the back, or along the outer border, in the Ammonite. I place before you examples from the gault of Folkstone, in which the shell remains,—from the lias of Watchett and the Kimmeridge clay of Hartwell, with the internal nacreous coat only,—while in this common species from the chalk-marl of the Isle of Wight (*Lign.* 70), the shell is altogether wanting, the specimen being a cast of the interior, formed of argillaceous chalk.

In some examples, the outer shells and the partitions of the chambers having decomposed, casts of the cells have been formed (called "spondylites"), which fit into each other, and admit of being put together, so as to show the entire shape of the Ammonite. Many hundred kinds of Ammonites are known in the secondary formations, and certain species are restricted to particular rocks. Thus, for example, the chalk-marl of Sussex abounds in three species (*Lign.* 68, *figs.* 7, 9, and *Lign.* 70), which do not occur either in the chalk above, or in the gault below; and in every locality of the chalk-marl in England, and on the continent, these have been met with.* The membranous tube of the siphuncle sometimes occurs in a fossil state; the black substance of the fossil tube has been analyzed, and found to consist of animal membrane, permeated by carbonate of lime.†

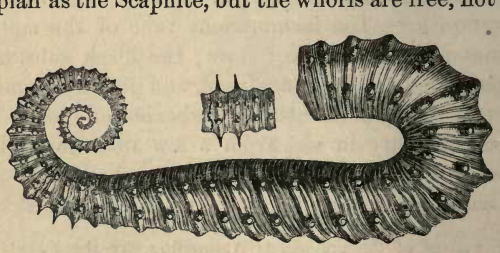
Ammonites vary in size from a few lines to twelve or fourteen feet in circumference; in the chalk-cliffs of the Sussex coast and in the limestone of the Isle of Portland,

* For figures of the cretaceous Ammonites, see the Fossils of the South Downs; Sowerby's Mineral Conchology; D'Orbigny's Paléontologie Française; and especially the late Mr. D. Sharpe's Monograph, published by the Palæontographical Society.

† Dr. Prout is of opinion that the black colour has originated from decomposition; the oxygen and hydrogen of the animal membrane having escaped, and carbon evolved, as happens when vegetable matter is converted into coal, under the process of mineralization. The lime has taken the place of the oxygen and hydrogen, which existed in the tube before decomposition.—*Dr. Buckland's Bridgewater Essay*, p. 352.

enormous specimens are often seen imbedded. The Ammonite was evidently a gregarious animal, for it occurs in extensive clusters in some of the cretaceous, oolitic, and liassic rocks.

27. TURRILITE, HAMITE, &c.—*Baculites, Turrilites, Hamites, Scaphites, Ancyloceras*, and other genera of multilocular shells, abound in the chalk-marl, gault, and greensands. The Baculite is most easily understood by supposing it to be an ammonite quite unrolled and perfectly straight; just as an orthoceras may be said to be a straight nautilus. The Turrilite (*Lign.* 68, *fig.* 2) may be described as an ammonite twisted in a turreted, instead of a discoidal, form: and the Hamite (*Lign.* 68, *fig.* 6), as a similar structure in the shape of a hook, coiled up at the smaller extremity. The Scaphite has the shell at first closely convoluted, but the last or body chamber is somewhat lengthened out until its mouth is suddenly turned again towards and almost against the spiral portion. The Ancyloceras is curled on the same plan as the Scaphite, but the whorls are free, not touch-

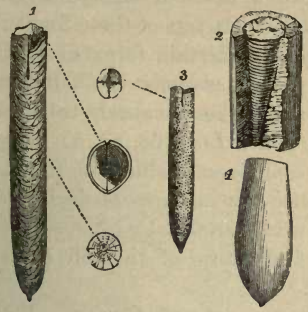


LIGN. 71.—ANCYLOCERAS MATHERONIANUS, D'ORB.
From the Lower Greensand, or Neocomian, of France.
(The original is about 2 feet in length.)

ing each other. These shells sometimes attain a large size; some fragments of Turrilites indicate that the original shell exceeded two feet in length. Very large specimens of Ancyloceras (*Lign.* 71) have been found in the lower greensand of Kent, Isle of Wight, and other places. The first speci-

mens of Baculites, Turrilites,* Hamites, and Scaphites, from the British strata, were discovered in my early researches, in Hamsey marl-pits, near Lewes.†

28. The Belemnite.—Among the innumerable relics of marine animals which occur in the secondary deposits, there



Lign. 72.—Belemnites; *one-third natural size.*

Fig. 1. *Belemnitella mucronata*;‡ from Chalk, Brighton. On the right of the figure is a view of the aperture; and beneath it a transverse section of the Belemnite, showing the radiated structure.

2. Portion of a Belemnite containing the internal chambered shell, called the *phragmo cone*; from the Oolite.

3. *Belemnitella quadrata*; from Chalk, Beauvais, France; the quadrangular cavity is shown in the upper figure on the left.

4. *Belemnites dilatatus*; from the Lower Greensand, France.

are none that have excited so much curiosity, and given rise to so many conjectures as to their nature and origin, as the fossils termed *Belemnites* by geologists, and which are generally known as *thunderbolts*. These are long, cylindrical, or

* The English Turrilites, comprising those collected by Dr. Mantell, have been fully illustrated and described in the Monograph on the Chalk Cephalopods, by Mr. D. Sharpe,—the last work of that eminent and lamented geologist.

† See Sowerby's Mineral Conchology, vol. i. tab. 18. Figures of Turrilites, Scaphites, &c., are given in Medals of Creation, vol. ii. p. 484—491.

‡ See Medals of Creation, vol. ii. p. 457. *Belemnitella* is the generic name of the Belemnites having a fissure down the ventral side of the alveolus, or cavity which receives the phragmocone.

fusiform stones, more or less pointed at one extremity, and having at the other and larger end a conical cavity, which is either occupied by a chambered shell, or filled up with the clay, sand, or stone in which the Belemnite happens to be imbedded. The substance of these bodies is invariably calcareous spar, of a radiated structure (*Lign.* 72, *fig.* 1). Such are the usual characters of these fossils, of which there are numerous species; certain forms abounding in the cretaceous strata. A very common chalk Belemnite is figured, *Lign.* 72, *fig.* 1; and the peculiarly transparent and small species from the gault, *Lign.* 68, *fig.* 5. These bodies were the osselets of cephalopods allied to the *Sepia*, and which probably, like those animals, possessed an ink-bag, mandibles, large eyes, and arms furnished with acetabula or suckers;* but no traces of the form of the soft parts have hitherto been discovered.

29. CRUSTACEANS OF THE CHALK.—Both of the two great tribes into which crustaceans are divided, namely, the *Malacostraca* (Crabs, Lobsters, &c.) and the *Entomostraca* (Water-fleas, King-crabs, &c.), are abundantly represented in the chalk series. Specimens of several of the larger crustaceans have been obtained from the lower chalk of Sussex,† Kent, and Cambridgeshire, and also from the cretaceous rocks of Germany;‡ among these are three or four species of *Enoploclytia*, a genus allied to the Lobster. In these specimens the filiform antennæ, the abdominal segments, and the caudal appendage, or tail, are preserved.§

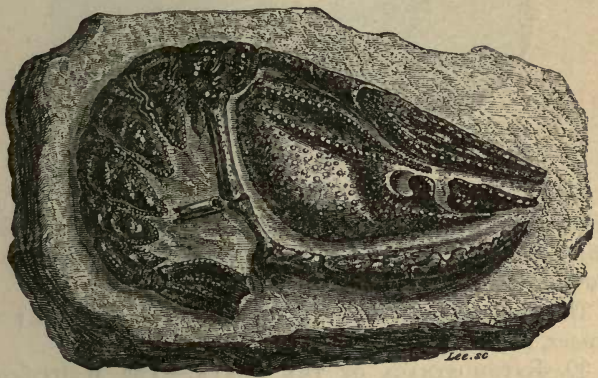
* Medals of Creation, vol. ii. p. 451—459.

† A noble example of *Enoploclytia Sussexiensis* is figured (with other valuable specimens of the same species, of *E. Leachii*, and of other forms) in plate 38* of Dixon's Fossils of Sussex.

‡ Dr. A. E. Reuss has beautifully illustrated the Bohemian specimens in his Verstein. böhm. Kreidef., and Trans. Acad. Vienn. vol. vi.

§ Medals of Creation, vol. ii. p. 517.

In the gault, smaller crab-like crustaceans belonging to extinct genera of the anomurous group have been obtained at Ringmer, near Lewes, Folkstone, and elsewhere.* In the Speeton clay of Yorkshire, Professor Phillips has discovered a beautiful species of Crayfish.† The greensand near Lyme Regis, in Dorset, has yielded some very interesting specimens of crustaceans; and the lower greensand of Kent and the Isle of Wight contains many remains of this family; some strata at Atherfield especially abound with a small species of lobster-like crustacean (*Lign.* 73).‡



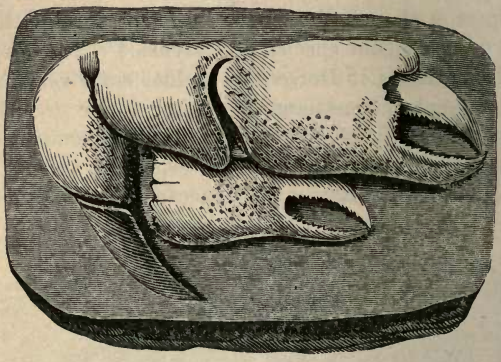
LIGN. 73.—MEYERIA VECTENSIS.
From the "Lobster-bed" of the Lower Greensand, at Atherfield, Isle of Wight.

In the limestone of St. Peter's Mountain, the claws of a small species of Crab are frequently met with (*Lign.* 74), but without any other vestiges of the animal. MM. Faujas St. Fond and Latreille have very ingeniously explained this fact, by showing that these remains belonged to a species of

* Medals of Creation, vol. ii. p. 513. † Ibid. p. 519.

‡ Some of the layers of the lower greensand at Atherfield contain so many remains of these small macrurous crustacea, as to be termed the "*Lobster-beds*." See Geology of the Isle of Wight, pp. 164, 169.

parasitical crustacean, which, like the common hermit-crab (*Pagurus*) of our seas, had the body covered by a delicate



LIGN. 74.—CLAWS OF A FOSSIL HERMIT-CRAB; FROM MAESTRICHT.
(Mesostylus Faujasii.)

membrane, the claws alone having a shelly case; hence the latter might be found in a fossil state, while of the other parts of the crustacean no traces would remain.*

This species is met with in the flinty chalk of Kent and Sussex, and also in Hanover and Bohemia.

30. ENTOMOSTRACA OF THE CHALK.—The Water-fleas and Sea-shell-fleas, well known to naturalists as minute bivalved crustaceans, the former abounding in rivers and ponds, the latter in seas of nearly all depths, occur very abundantly in the fossil state. Many of the tertiary deposits, both those of freshwater and those of marine origin, contain them, and some are full of their tiny carapace-valves.†

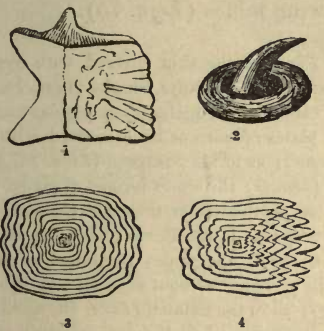
* Medals of Creation, vol. ii. p. 515.

† See above, p. 254; also Monograph of the Tertiary Entomostraca of England, by T. Rupert Jones, Palæont. Soc. 1856; M. Bosquet's Memoir on the French and Belgian species in the Brussels Transactions; and Dr. Reuss's papers in Haidinger's Abhandlungen and the Vienna Transactions.

The cretaceous deposits are often crowded with the remains of the marine forms, such as *Cythere*, *Bairdia*, *Cytherella*, &c. These are extremely abundant in all the beds of chalk, both in England and on the continent, and in the gault also.*

The greensands in England have not afforded many specimens; but M. Cornuel † has discovered several in the lower greensand of France.

31. FISHES OF THE CHALK.—The fossil fishes of the white chalk were known only by the teeth, which abound in almost every quarry, until my researches in the chalk-pits



LIGN. 75.—SCALES OF THE FOUR GROUPS OF FISHES.

Fig. 1. Scale of *Lepidotus*; a fish of the *Ganoid* group.
2. — *Ray*; — *Placoid* — .
3. — *Salmon*; — *Cycloid* — .
4. — *Beryx*; — *Ctenoid* — .

around Lewes brought to light many extraordinary specimens, and showed how such delicate remains could be de-

* See Rupert Jones's Monograph of the Cretaceous Entomostraca, Palæont. Soc. 1849; and Memoirs on the same subject by MM. Bosquet and Reuss.

† Mém. Soc. Géol. France, deux sér. vols. i. and iii.

veloped.* Professor Agassiz, by whose genius and labours this department of palæontology has been most successfully elucidated, adopted a classification of fishes, founded upon the peculiar structure of the scales — a method of great utility to the geologist, since the mutilated state in which the fossil remains of fishes generally occur often renders futile all attempts to refer them to the orders and genera of other systems of Ichthyology.†

32. SCALES OF FISHES. — In his great work on fossil fishes, M. Agassiz includes all fishes in four orders, which are distinguished by the structure of the scales, as exemplified in the following tables (*Lign.* 75).

Order I. The *Placoid;* the skin covered with irregular enamelled plates, as in the Rays, Sharks (*Lign.* 75, *fig.* 2).

II. The *Ganoid;* the scales of an angular form, and composed of plates of horn or bone covered with a thick layer of enamel; as in the Sturgeon (*Lign.* 75, *fig.* 1).

III. The *Ctenoid;* the scales formed of plates, which are toothed or pectinated on their posterior margin or edge, like a comb; as in the Perch (*Lign.* 75, *fig.* 4).

IV. The *Cycloid;* the scales composed of simple laminæ of horn or bone, without enamel, and having smooth borders; as in the Salmon (*Lign.* 75, *fig.* 3.)‡

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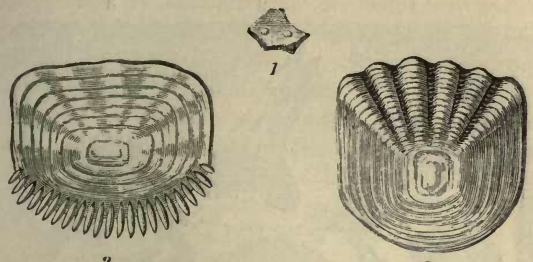
* I believe the Fossils of the South Downs (1822) contained the first published figures of fishes from the English chalk.

† Recherches sur les Poissons Fossiles, par Louis Agassiz; five volumes (folio) of coloured figures, and two quarto vols. of letter-press. In some respects the arrangement of the fossil fishes according to their scale-structure is useful to the collector and student; but, as it is not a perfectly natural classification, it must be only accepted as a useful empirical method for grouping the fossil remains of fish that commonly occur to the collector. The most accurate classification, combining both recent and fossil fishes, is that furnished by Sir P. Egerton to Mr. Morris, for the heading of the list of fishes in his catalogue of British Fossils, p. 315. This is slightly varied from Müller's classification as modified by Prof. Owen.

‡ See Medals of Creation, vol. ii. p. 566.

Patches of scales are very abundant in some of the chalk-strata of the south-east of England; and occasionally, in



LIGN. 76.—SCALES OF FISHES IN FLINT.

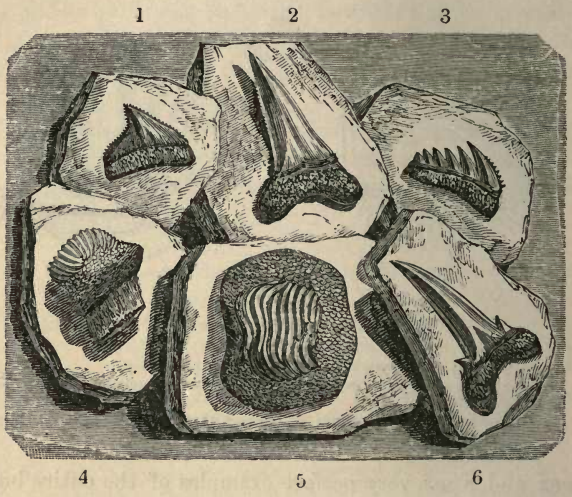
Fig. 1. A fragment of flint containing two scales, of the natural size.
2. One of the scales highly magnified; it belongs to the species of *Beryx* figured in *Lign.* 75.
3. The other scale highly magnified; it belongs to the species of *Osmeroides* figured in *Lign.* 79, *fig.* 1.

Sussex and Kent, very perfect examples of the entire body of the fish, with the fins attached, are obtained, and which by proper dissection may be beautifully displayed.* Scales and teeth are occasionally found in flint;† sometimes adherent to the surface, and in other instances inbedded in the stone. A fragment of flint to which two minute scales are attached is figured in *Lign.* 76, *fig.* 1; and the scales, highly magnified, are represented in *figs.* 2 and 3.

* For directions how to clear chalk-fishes, see Medals of Creation, vol. ii. p. 635. All the Author's best specimens, most of which are figured in the work of M. Agassiz, are now in the British Museum. See Petrifactions and their Teachings, p. 409, &c.

† See the Rev. Mr. Reade's very interesting notice of the occurrence of Spiniferites and Fish-scales in flint, with numerous figures, in the Annals of Nat. Hist. vol. ii.; also Capt. Alexander's notice in the Journ. Geol. Soc. vol. x. 334.

33. TEETH OF SHARKS, &c.—Teeth of several genera of fishes abound in the cretaceous deposits: and of these, by far the greater number belong to the Sharks; a family which



LIGN. 77.—TEETH OF SHARKS; FROM THE CHALK NEAR LEWES.

Fig. 1. Galeus pristodontus.
— 3. Notidanus microdon.
— 5. Ptychodus polygyrus.
Fig. 2. Lamna crassidens.
— 4. Ptychodus polygyrus.
— 6. Lamna elegans.

in the ancient, as well as in the modern seas, appears to have been confined by no geographical limits. A group of some of the usual forms is represented in *Lign.* 77. These teeth possess a high polish, and are in an excellent state of preservation; they generally occur detached, owing to the decomposition of the jaws, which from their cartilaginous nature are but seldom preserved. A few specimens of the

fishes termed *Hybodus* * have, however, been found with several rows of teeth attached to the jaws.

Large flat teeth, having a series of deep angular plaitings on the crown, surrounded by a border of papillæ (*Lign.* 77, *figs.* 4, 5), are very abundant, and are commonly known as "palates" or palatal teeth. They belong to a genus of the shark family called *Ptychodus* (rugous teeth), allied to the *Cestracion* or Port Jackson Shark. These teeth are not unfrequently met with in groups, and retaining, more or less perfectly, their original relative positions. Dorsal rays, or fin-bones, belonging to these fishes, and three feet in length, are occasionally met with in the chalk.† Palatal teeth referable to the existing genus *Cestracion* have been found in the chalk of Kent ‡ and Sussex; and with these Sir P. Egerton finds reason to associate the dorsal spines found in the same quarries, and formerly known as *Spinax major*.§ Vertebræ and other remains of sharks have been obtained in considerable numbers from the chalk of the south-east of England: their coprolites also are not rare.

The mandible or anterior part of the maxillary bone of a fish belonging to a very remarkable family, of which the *Chimæra* is the only living type,‖ was found in the chalk-marl at Hamsey, near Lewes, many years since, associated with turrilites, hamites, &c., and subsequently examples have been met with in the lower chalk and lower greensand, and many other forms have been discovered in secondary and tertiary strata; thus affording evidence that the ancient seas were inhabited by several genera of this curious and now limited group.¶

* Medals of Creation, vol. ii. p. 591; Geology of the Isle of Wight, p. 170.

† Medals of Creation, vol. ii. p. 578.

‡ Dixon's Fossils of Sussex, pl. 32, fig. 8.

§ Medals of Creation, vol. ii. p. 584. ‖ Ibid. p. 589.

¶ Sir P. G. Egerton, in 1847, read before the Geological Society an ad-

34. SAUROIDS AND HYPSODON.—Teeth of fishes belonging to that division called *Sauroid*, from their combining in

LIGN. 78.—MAXILLARY BONE OF A FISH ALLIED TO THE CHIMÆRA; FROM THE CHALK NEAR LEWES.
(Edaphodon Mantelli; half the natural size.)

their structure certain characters of reptiles,* have been found in the chalk. Such as the *Belonostomus*, *Caturus*, *Lophiostomus*, and *Pomognathus*; the first two of which have species in the lias also.†

A genus of extinct fishes, allied to the Pikes and Mackerels, and established by M. Agassiz from the examination of some vertebræ and other bones, is named *Hypsodon*, from the straight and pointed form of the teeth. A jaw with teeth, some vertebræ, and the *os hyoides* of this fish were discovered in the chalk near Lewes, and are figured in Pl. xlii. of the Fossils of the South Downs. Their apparently reptilian character led me to consider them as belonging to a saurian, until I obtained a considerable portion of the cranium, jaws with teeth, the bone that articulates the lower jaw with the skull, and several biconcave vertebræ, im-

mirable memoir on the fossil chimæroid fishes; and his revised nomenclature of this group is given by Mr. Dixon, *Fossils of Sussex*, p. 203.

* Medals of Creation, vol. ii. p. 617.

† The above-mentioned fishes, together with many others, are beautifully illustrated in Dixon's Geology and Fossils of Sussex.

bedded in a block of chalk, and belonging to the same individual.*

35. Osmeroides. (*Lign.* 79, *fig.* 1.)—Of the cycloid group, or fishes with scales of a cycloid or circular form, smoothly margined, and composed of plates of horn or bone without enamel, there are two or three species belonging to the wide-mouth Salmon family (scopelidæ), which occur in the lower chalk near Lewes. These ichthyolites are exceedingly beautiful, and generally have the body uncompressed, and as round and perfect as when the fishes were alive. The entire cranium, opercula, branchial rays, and fins are preserved in some examples. From the close affinity of these fishes to the Smelt (*Osmerus*), they have been named *Osmeroides*. In one specimen I succeeded in clearing away the chalk, so as to expose the entire fish, which lies six inches in relief, being attached by the back to the block of stone; the mouth is open, and the opercula, or gill-covers, and the branchial arches are expanded; the pectoral, dorsal, and ventral fins are in their natural position.†

Even to those whose curiosity has not previously been awakened by the Wonders of Geology, the examination of these petrified inhabitants of the ancient chalk-ocean cannot fail to excite deep interest; and I have often seen the man of fashion, as well as the philosopher, gaze in mute astonishment on these "relics of a former world."

36. Macropoma. (*Lign.* 80, *fig.* 2.)—A fish, bearing some semblance to the large Carps in its general outline, but essentially differing in its structure, is the most remarkable ichthyolite which my researches in the chalk-quarries

* This fine specimen is now in the British Museum, with other remains of the Hypsodon. Petrifactions, &c., p. 444.

A splendid specimen of jaws and premaxillary bones, with numerous teeth, that differ from the Hypsodon Lewesiensis in being slightly curved, is in the choice collection of Toulmin Smith, Esq. of Highgate. Two species of Hypsodon have been identified in the London clay.

† Medals of Creation, vol. ii. p. 626, pl. 2; and Petrifactions, p. 445.

around Lewes have brought to light;* but it was not till after many years of persevering research that the nature of the original was fully illustrated. This fish when at maturity must have exceeded two feet in length: its skeleton is massy, indicating a powerful frame; and its thick scales, strong fins, and sharp teeth show that it was a voracious animal, capable of pursuing and overtaking live prey. The head is very large; being nearly equal to one-fourth the length of the body. The scales are large, and are covered, on the exposed surface, with pointed elongated cylinders. The opercula are very long.† The rays of the fins are large and rigid, especially those of the anterior dorsal, which are armed on each side with rows of sharp spines. The tail is very large, rounded, and fan-shaped, with strong equal rays, supported by the inferior and superior spinous processes of the caudal vertebræ. The form of the jaws and teeth is also remarkable, but my limits will not admit of further details. In every example, there is present in the abdomen an oblong cylindrical body, apparently terminating at one end in a cul-de-sac: its surface has a squamous appearance, owing to the separation and partial exfoliation of the membranes of which its walls are composed. Under the microscope, the ramification of the vessels through these tissues is distinctly seen. This appear to have been either the air-bladder‡ or the stomach of the fish. *Coprolites* (or fossil excrements), having a slightly convoluted form, are often found with the remains of the Macropoma. Minute scales

* Fossils of the South Downs; where it is described under the name of *Amia Lewesiensis*. The largest specimen therein figured (Pl. 38) was presented to Baron Cuvier, and is now in the museum of the Jardin des Plantes. Medals of Creation, vol. ii. p. 620.

† Whence the name *Macropoma*; μακρὸς, *long*, and πῶμα, *operculum*. Petrifactions and their Teachings, p. 436.

‡ See Prof. Williamson's observations on this subject, Philos. Transact. 1849, p. 462.

and bones of fishes are occasionally imbedded in the substance of these coprolites, affording evidence of the carnivorous habits of the Macropoma.

A fine specimen of Macropoma has lately been obtained from the Purbeck strata by Mr. S. H. Beckles, the indefatigable investigator of the fossils of the Wealden, and of the mammalian fossils of Purbeck in particular. This interesting discovery indicates a new point of relationship between the Wealden and the Cretaceous faunas.

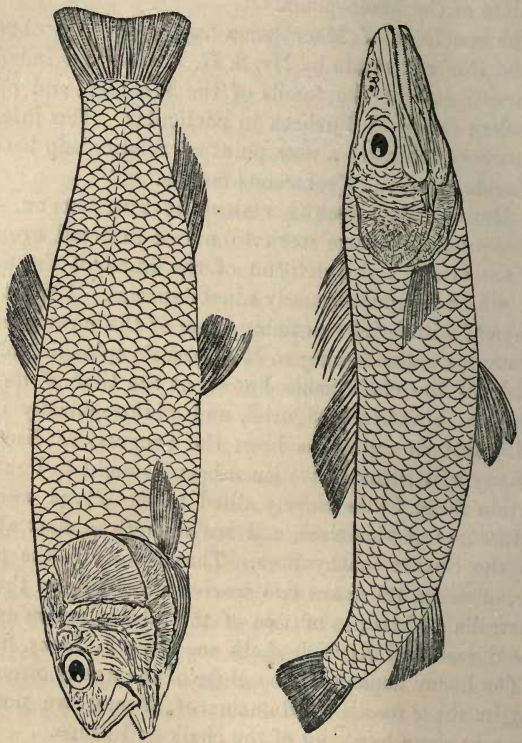
37. Beryx; and other fishes of the Chalk. — It would require a separate work to notice in detail even my own discoveries in this division of the fauna of the chalk-ocean, which comprises nearly ninety species. I must content myself with briefly noticing some of the most interesting examples, and referring to M. Agassiz's splendid volume, in which all the chalk-fishes known at the time of its publication are beautifully figured, and philosophically interpreted. But so rapid has been the progress of discovery that many new genera have since been brought to light.*

Certain fossil fishes closely allied to the *Perch* were my first treasures of this class, and are among the most abundant of the Sussex ichthyolites. They belong to the genus *Beryx*, of which there are two species now living in the seas of Australia. Outlines of two of the most common species of the Sussex and Kentish chalk are given in *Ligns.* 82 and 83. The horny capsule of the globe of the eye is often preserved in these fossils.† Remains of Beryx are not uncommon in some localities of the chalk in Europe.

The annexed figures (*Ligns.* 79, 80, 81, 82, 83) are restored outlines of seven of the fishes of the Chalk, executed by Mr. Joseph Dinkel, the eminent artist employed by M. Agassiz.

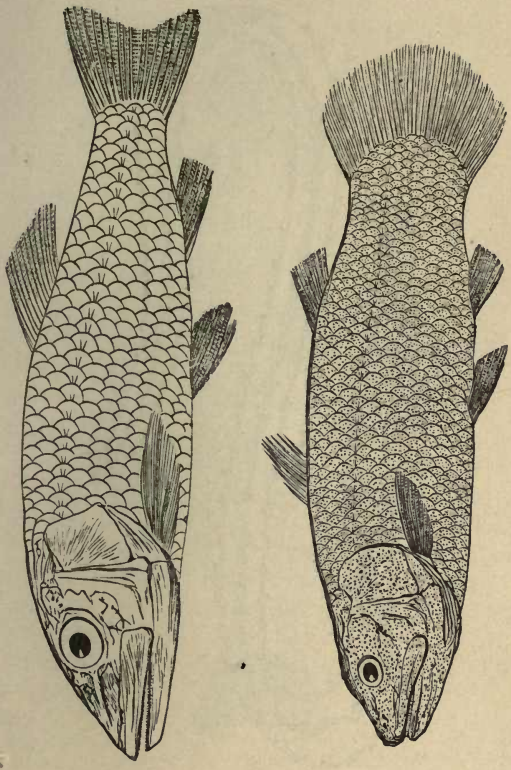
* See Morris, Catalogue of British Fossils, 1854.

† Medals of Creation, vol. ii. p. 624.



LIGN. 79.—Fig. 1. OSMEROIDES MANTELLI. Length 12 inches. From Lewes chalk-pits.

Fig. 2. ACROGNATHUS BOOPS. Natural size. From near Lewes.



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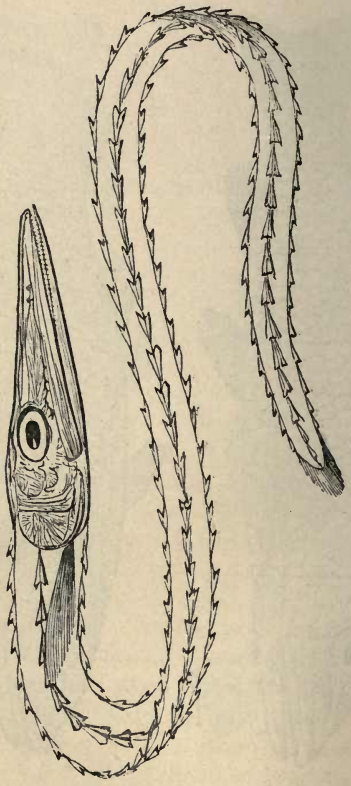
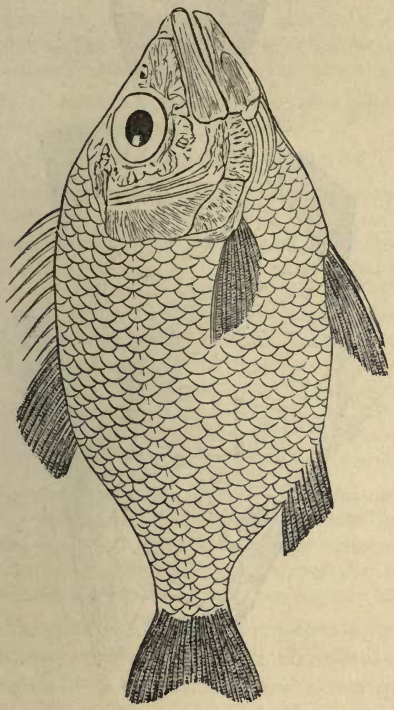
LIGN. 80.—Fig. 1. AULOLEPIS TYPUS. Length 6 inches. From Clayton, Sussex.

Fig. 2. MACROPOMA MANTELLI. Length 24 inches. From the chalk-quarries near Lewes.



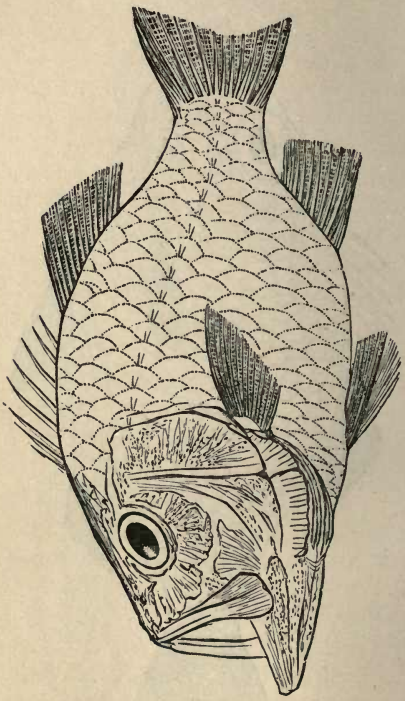
LIGN. 81.—DERCETIS ELONGATUS. Length 16 inches. From Lewes.

Fragments of the cylindrical body of fishes of this genus occur abundantly in the chalk of some localities (see p 335). The outline represents a specimen collected from the chalk near Lewes; it is the only instance in which the cranium remains.



LIGN. 82.—BERYX RADIANS. Length 7 inches. From the chalk-marl, near Lewes.

This species is generally found in the lower chalk and chalk-marl: specimens have been collected at Lewes, Clayton, Steyning, and Arundel, in Sussex; and at Burham and near Maidstone, in Kent.



LIGN. 83.—BERYX LEWESIENSIS. Length 12 inches. From the Lewes Chalk.

This is the most abundant of the Sussex ichthyolites; and is called *Johnny Dory* by the quarrymen. Detached scales are very frequent in the chalk of the South Downs, and also in that of Kent and Surrey. Some fine specimens of this species have been found in the chalk of Chatham and Maidstone.

Lign. 79, *fig.* 1. *Osmeroides Mantelli.* This figure conveys a correct idea of the general outline of the fossil *Scopelidæ* found in the Lewes chalk.

Lign. 79, *fig.* 2. *Acrognathus boops.* There are but few specimens of this small fish. The relatively large jaw and eye are indicated by the name. The upward bend of the caudal extremity is doubtless accidental. This fish belongs to the Salmon tribe.

Lign. 80, *fig.* 1. *Aulolepis typus.* This is a unique specimen of a fish six inches long, belonging to the *Salmonidæ.*

Lign. 80. *fig.* 2. *Macropoma Mantelli.* See page 357.

Lign. 81. *Dercetis elongatus.* Fragments of the elongated subcylindrical body of this fish very frequently occur in the chalk of Sussex, Kent, and Hampshire. It is found also at Norwich, and an allied species in Westphalia. Examples, two feet and even more in length, are occasionally met with; and yet but few instances are known in which any vestiges of the skull or of the tail can be traced. In the specimen from which the figure was taken, the parts represented were clearly defined. The Dercetis had on the sides three rows of dermal scutcheons (like those of the Sturgeon), that extended over the body, and the intervals between them were covered with small scales; in most specimens the latter only remain. (See Medals of Creation, vol. ii. p. 622.)

Lign. 82. *Beryx radians.* *Lign.* 83. *Beryx Lewesiensis.* Several examples of these ancient fishes of the Perch-tribe have been found as perfect as in these delineations. Another and more delicate species, with a very small head (*Beryx microcephalus*), is occasionally obtained from the chalk-marl, exquisitely preserved.

In the other subdivisions of the cretaceous formation, remains of fishes occur more or less abundantly in various parts of England,* the Continent, and America. One locality only can here be mentioned; Glarus in Switzerland

* Of the numerous species belonging to the nearly 50 genera of fishes represented in the Upper and Lower Chalk of England, only five or six occur in lower cretaceous beds of this country, with one or two species of additional genera. An account of the remarkably fine and well-preserved jaw, with teeth, of the fossil Shark known as *Hybodus*, discovered by Mr. Ibbetson in the Lower Greensand at Atherfield, is to be found in the *Isle of Wight*, p. 169

has long been celebrated for the profusion and variety of its ichthyolites, which occur in a very hard, black, laminated rock, highly bituminous, and scarcely distinguishable lithologically from some of the most ancient slate-rocks. But from the characters of the fossil fishes, which are all of cretaceous genera, M. Agassiz was enabled to prove that the Glarus slates belong to the chalk-formation; the altered condition of the rock having resulted from the effect of high temperature under great pressure.

In concluding this cursory notice of the fishes of the cretaceous epoch, I would remark that nearly all the genera, and probably all the species, are extinct, but related to tertiary forms. This result is in accordance with that derived from the examination of the zoophytes, mollusca, and other organisms, which have come under our notice in the course of this review.

38. REPTILES OF THE CHALK.—The remains of reptiles discovered in this formation, though not very numerous,* are sufficient to arrest attention, when contrasted with the entire absence of all traces of warm-blooded animals. We perceive, as it were, the first indications of that remarkable discrepancy in the relative numerical proportion of the mammalia and the reptilia which distinguishes the secondary from the tertiary and modern epochs.

The most extraordinary of the reptiles peculiar to the chalk is the Mosasaurus of Maestricht (*ante*, p. 319). Relics probably of the Maestricht species, as well as of two or three allied forms, have been met with in the English chalk.†

Teeth of crocodiles are mentioned by Baron Cuvier as having been obtained from the chalk at Meudon.

* The English species are in number about twenty-four, and belong to twelve genera. They are fully described and illustrated in Owen's Monograph of the Cretaceous Reptiles (Palæont. Soc.); and in Dixon's Fossils of Sussex.

† See Medals, vol. iii. p. 708.

A considerable portion of a spinal column composed of concavo-convex vertebræ, with many ribs, and part of the pelvis, of a small lizard, were found in the chalk near Maidstone; and another specimen of the anterior portion of the spine, with part of the cranium, was afterwards obtained by Mrs. Smith, of Tunbridge Wells. These two portions apparently belonged to one specimen of the *Dolichosaurus longicollis* of Owen.* A jaw, with numerous subulate teeth, anchylosed by their base to an alveolar parapet of bone, as in the recent Iguana, has been discovered in chalk near Cambridge. This relic illustrates Prof. Owen's *Raphiosaurus*.

Remains of two genera of marine reptiles, the Ichthyosaurus and Plesiosaurus, occur, though rarely, in the chalk of Sussex, Kent, Cambridgeshire, and Dorsetshire.†

From the lower greensand of Kent one of the most interesting specimens of the Iguanodon has been obtained; and in similar strata at Hythe, have been found numerous bones of a gigantic marine reptile, to which are also ascribed certain large conical striated teeth (*Polyptychodon*), that occur in the lower chalk and the upper and lower greensands of various localities.‡

That the *Pterodactyles*, those marvellous flying reptiles, existed during the cretaceous epoch, we have proof in several specimens of bones of the extremities, and of parts of the cranium, and jaws with teeth,§ obtained from the chalk-pit at Burham, in which the fossil turtle, presently to be noticed, was discovered.

39. Fossil Turtles.—Of the Chelonian reptiles, or Turtles, remains of marine species are found abundantly in the

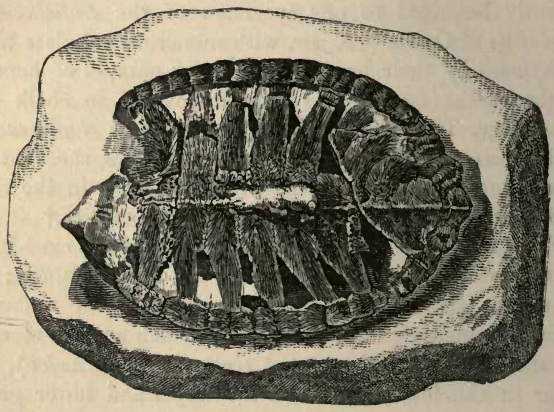
* Medals of Creation, vol. ii. p. 711.

† I have received a vertebra of a Plesiosaurus from the chalk near Blandford, through the kindness of Mr. J. Shipp.

‡ Medals of Creation, vol. ii. p. 683.

§ Mr. Bowerbank's collection is enriched with several unique specimens of pterodactylian jaws and other remains.

limestone of St. Peter's Mountain, and in the slaty beds of Glarus. In the white chalk of England relics of this kind are rare; but a few beautiful specimens of a small and very peculiar Turtle have been found in the chalk of Kent.* This reptile, which I have named, in honour of its discoverer,



LIGN. 84.—FOSSIL TURTLE; FROM THE CHALK.

(Chelone Benstedi: one-third the natural size.)

Chelone Benstedi, appears to blend the characters of the Chelonians, or marine turtles, with those of the *Emydes* or freshwater forms; and since my description of the fossil † figured in *Lign.* 84, two other specimens have been found, of about the same size, and presenting similar characters. The upper part of the carapace delineated in the drawing,

* At Burham, between Chatham and Maidstone.

† See the notice of a fossil Turtle from the Chalk, Philos. Trans. May, 1841; with two plates. Prof. Owen also has figured and described this species in his Monograph of Cretaceous Reptiles (Palæontograph. Society), 1851, and Dr. Reuss, in the Transactions of the Vienna Academy of Sciences, vol. x. 1855.

Lign. 84, can be removed, so as to expose the bones of the plastron, or sternal plates, beneath. This fossil is six inches in length, and three and half in breadth.

40. SUMMARY.—The characters of the Cretaceous Formation, as shown by these investigations, are those of a vast oceanic basin, filled up with organic and inorganic debris enclosing innumerable remains of the successive generations of marine animals which lived and died in its waters, through periods of incal ulable duration.

The fossil fuci indicate that the chalk-ocean possessed the usual marine flora; while the drifted masses of wood bored by teredines, and the fir-cones, stems of cycadeous plants, leaves of ferns, and bones of terrestrial reptiles, prove that its shores were bounded by dry land, which was clothed with forests, and inhabited by colossal oviparous quadrupeds. Of the higher orders of animals no unquestionable relics have yet been discovered.

LECTURE IV.

Part II.

1. Geology of the South-east of England. 2. Geological phenomena between London and Brighton. 3. London and Brighton Railway Sections. 4. The Wealden and Purbeck Formation. 5. Wealden of the Sussex coast. 6. Pounceford. 7. Tilgate Forest. 8. Ripple-marks on Wealden sandstone. 9. Subdivisions and extent of the Wealden. 10. Wealden of the North of Germany. 11. Wealden of the Isle of Wight. 12. Fossil Trees at Brook Point. 13. Wealden of the Isle of Purbeck. 14. Coves in the S. W. of Purbeck. 15. The Isle of Portland. 16. Petrified Forest of the Isle of Portland. 17. Mantelliæ. 18. Extent of the Dirt-bed. 19. Organic Remains of the Wealden. 20. Fossil Vegetables. 21. Fossil Cycadeous Plants. 22. Clathraria Lyellii. 23. Fruits of Coniferous Trees. 24. Univalve Shells of the Wealden. 25. Bivalve Shells of the Wealden. 26. Crustaceans of the Wealden. 27. Wealden Insects. 28. Wealden Fishes. 29. Reptiles of the Wealden. 30. Fossil Turtles. 31. Marine Reptiles. 32. Crocodilian Reptiles. 33. Fossil Teeth of Crocodiles. 34. Fossil Crocodile of Swanage. 35. The Dinosaurians. 36. Megalosaurus. 37. Iguanodon. 38. Teeth and Jaws of the Iguanodon. 39. The Maidstone Iguanodon. 40. Vertebræ of the Iguanodon. 41. Bones of the extremities. 42. Magnitude and proportions of the Iguanodon. 43. The Hylæosaurus. 44. Pterodactyles and Birds of the Wealden. 45. The Country of the Iguanodon. 46. Sequence of Geological changes. 47. Retrospect.

1. Geology of the south-east of England.—From the foregoing survey of the marine formation of the Chalk, we turn to the remarkable fluviatile deposits of which the basin of the cretaceous ocean, in the south-east of England, was composed; in other countries, as I shall hereafter have occasion to remark, that ocean-bed was formed of the Oolite and other more ancient rocks. It will now be necessary to offer a few observations on the geology of the district in which the Wealden is so largely developed.

The strata of the south-east of England belong to three principal groups or formations. The *first* consists of the *Tertiary* sands, clays, and gravel, which occupy depressions in the chalk, and are described in the previous Lecture.

The *second* is the *Cretaceous* series (including under this term the Chalk, Chalk-marl, Upper Greensand, Gault, and Lower Greensand), which form the most striking features in the physical geography of the country. The upper division of this formation constitutes the South Downs, which, from the bold promontory of Beachy Head, traverse the county of Sussex from east to west, and pass through Hampshire into Surrey; from Godalming the chalk-hills extend by Godstone into Kent, where they are called the *North Downs*, and terminate in the line of cliffs that stretches from Dover to Ramsgate. The lowest member of the chalk-series, the *Lower Greensand*, appears as a chain of hills of irregular elevation, skirting the escarpments of the chalk-downs; the *Gault* for the most part occupying the intermediate valley.

The *third* group fills up the area between the North and South Downs; the most elevated masses form the *Forest-ridge*, which traverses the district in a direction nearly east and west, and is composed of alternations of sandstones, sands, shales, and clays, with a deep valley on each flank; this is called the *Weald:* hence the geological designation of the whole series. From the central ridge of the Wealden, which varies in height from 400 to 800 feet, and stretches from Fairlight Down near Hastings, on the east, to beyond Horsham on the west, the strata dip away or diverge on each side towards the Downs (thus constituting an *anticlinal axis*), and disappear on either side beneath the lowermost beds of greensand. There are conclusive proofs that the Wealden strata were originally covered by the chalk, and that their present position and appearance are attributable to changes which have taken place subsequently to the cretaceous epoch.*

* See Geology of the South-east of England, chap. xi.; and Lyell's Manual, chap. xix.

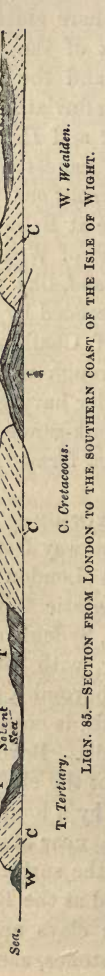
2. GEOLOGICAL PHENOMENA BETWEEN LONDON AND BRIGHTON. — The direct turnpike-roads from London to Brighton pass over the whole series of these deposits, as well as those described in the previous lectures. Proceeding from the Thames, the observer at first traverses the modern silt of the river, and the ancient drift and alluvium, containing remains of elephants and other large mammalia; if he proceeds by Reigate, his road, through Clapham and Tooting, lies over beds of clay and gravel, which form part of the ancient shores of the London estuary. At Sutton he ascends the chalk-hills of Surrey, and travels along an undulated tract of country, formed by the elevated masses of the ancient cretaceous deposits just described. Arriving at the precipitous southern escarpment of the North Downs, a magnificent landscape, displaying the physical geography of the Weald, and its varied and picturesque scenery, suddenly bursts upon his view. At his feet lies the deep valley of Gault in which Reigate is situated, and immediately beyond the town, appears the elevated ridge of Lower Greensand, which, stretching towards the west, attains at Leith Hill an altitude of one thousand feet,* and to the east forms a line of sand-hills, by Godstone and Sevenoaks, through Kent, to the sea-shore. The Forest-ridge of the Wealden occupies the middle region, extending westward towards Horsham, and eastward to Crowborough Hill, its greatest altitude, and thence to Hastings, having on each flank the wealds of Kent and Sussex; while in the remote distance, the smooth and undulated summits of the South Downs appear like masses of grey clouds on the verge of the horizon.

Pursuing his route, the traveller passes through Reigate, along the valley of *Gault*, and over the *Lower Greensand* of Cockshut Hill, and arrives at the *Wealden*. The *Weald clay*, containing beds of fresh-water limestone, appears at

* See the "*Memoir on the Geology of the Country seen from the summit of Leith Hill,*" in Brayley's History of the County of Surrey.

Horley Common; and, while in the commencement of his journey the roads were made of broken chalk-flints, and at Reigate of cherty-sandstone, the materials here chiefly employed are the bluish-grey calcareous rock of the Weald. At Crawley sand and sandstone appear, and the road is constructed of grit and limestone, containing fluviatile shells, bones, and plants. Crossing *Tilgate Forest* and *Handcross*, over a succession of elevated ridges of sandstone, and through clay-valleys, produced by the alternations of the strata, he descends from the sandstone ridge at Bolney, near Cuckfield, and again journeys along a district of Weald Clay containing fresh-water limestone. *Greensand*, like that of Reigate, reappears at Hickstead, and is succeeded by a tract of *Gault;* and finally, entering a valley of Chalk-marl, he reaches a defile in the South Downs, through which the road winds its way to Brighton; the traveller having in the course of his journey passed from one chalk-range to the other, and crossed over the intervening area formed by the exposure of the Wealden.

3. London and Brighton Railway section.—A similar section is displayed along the line of railway from London to Brighton. Leaving the station at London bridge, the tertiary clays, rich with their characteristic fossils, are seen from beyond Deptford, by New Cross, Sydenham, &c.; and, near Croydon, beds of gravel appear, with interspersions of olive-green sand. The valley beyond Croydon, along the side of which the railway proceeds, is occupied by a thick bed of gravel resting on the chalk. Beyond the station called *Stoats'-nest*, is a fine section of the chalk-with-flint, and the North Downs are traversed by a long tunnel, carried through the solid chalk and emerging near Merstham, where the chalk-marl and firestone rise to the surface. The lower cretaceous clays and sands are passed at the Red Hill and Godstone stations, and the Wealden clays appear at Horley, and are succeeded by shales, limestones, sands, and sandstones, to the Crawley station.



LIGN. 85.—SECTION FROM LONDON TO THE SOUTHERN COAST OF THE ISLE OF WIGHT.

Passing through a long tunnel in the Wealden, we arrive at Balcombe, where laminated sandstone and shale are seen on each side the cutting. The general dip of the strata hitherto passed is to the *north-east;* but after crossing the deep Wealden valley beyond Balcombe, over a magnificent viaduct, the line runs along alternating layers of sands and clays, which dip to the *south-west;* we have therefore arrived on the southern side of the grand anticlinal axis of the Forest Ridge. The Wealden strata continue, with the same general inclination, by Hayward's Heath, which is traversed by a tunnel, to beyond St. John's Common, where they disappear beneath the lowermost greensand beds of the chalk formation. The gault, upper greensand, and chalk-marl succeed, and lastly the white chalk of the South Downs, at Clayton Hill, through the base of which a long tunnel passes, emerging on the south of the Downs. The remainder of the line to the Brighton station runs over or through hills and valleys of the white chalk.

Thus this railway passes through two ranges of chalk hills, *viz.* the North and South Downs, by tunnels; two of lower greensand, *viz.* near Red Hill in Surrey, and Hurstperpoint in Sussex; and two principal ridges of Wealden, *viz.* at Balcombe, and Hayward's Heath. If we take a line bearing more to the west; as, for example, from London to the southern shores of the Isle of Wight, in Sandown

Bay, we shall have the section represented in *Lign.* 85, which exhibits the entire series of the deposits, and their relative position in the south-east of England.*

The older tertiary or eocene strata, forming the site of London, are seen occupying a depression of the chalk; the North Downs of Surrey next appear,—then the anticlinal ridge of the Wealden,—the South Downs of Sussex and Hampshire succeed—covered on the south by the marine tertiary strata of Southampton,—then the depression in the strata occupied by the Solent,—the north of the Isle of Wight covered by fresh-water and marine eocene deposits,—next the highly inclined chalk-range of the Island—and lastly, the emergence of Wealden beds from under the lower greensand, in Sandown Bay.†

4. THE WEALDEN.‡—The tertiary basin of London af-

* The succession of strata is readily traced along the railway-lines on such geological maps as that of Knipe's, Greenough's, or the small map published by Stanford under the auspices of Sir R. Murchison.

† See page 389; and Geology of the Isle of Wight, p. 96.

‡ The whole of the fluvio-marine or river and sea deposits lying between the Portland stone and the lower greensand are here comprised under the name of *Wealden*. The fresh-water and estuarine beds in the Wealds of Kent and Sussex were first elucidated by the author of the "Wonders," and by Dr. Fitton; and subsequently Mr. Webster, Prof. E. Forbes, and others worked out the relations of the estuarine shales and limestones of Durlstone Bay, the Vale of Wardour, and other parts of Dorset and Wilts, and of some places in Bucks.

The Dorsetshire series, termed "Purbeck beds,' are below the clays and sands of the Wealden proper, which occur also in Swanage Bay; they possess more marine fossils than the latter, and indeed appear to have somewhat of an oolitic character in their organic remains; whilst such sea-shells as occur in the upper series are for the most part cretaceous in their relations. The flora, or plants, however, and the vertebrate remains of both groups of strata, the Purbeck and the Wealden proper, are more or less oolitic in their types.

Prof. E. Forbes, in 1850, subdivided the Purbeck beds into Upper, Middle, and Lower, and, in accordance with Mr. Austen's views, of the same year (Quart. Journ. Geol. Soc. vol. vi. p. 467), referred them to the

forded an example of the accumulation of detritus and organic remains in an inland sea or land-locked bay;—that of Paris, of marine and fresh-water sediments, deposited in a gulf open to the sea on the one side, and fed by rivers and thermal springs on the other;—the lacustrine formations of Auvergne, of the gradual precipitation of strata in the tranquil waters of lakes;—the cretaceous formation, of the operations which have taken place in the profound abyss of an ocean;—while the series of deposits to which the term *Wealden* is applied present the most striking instance of an ancient delta, with its brackish lagoons, hitherto discovered. Yet strange as it may appear, although these strata occupy the whole area between the North and South Downs—a tract of country traversed daily by hundreds of intelligent persons from the metropolis, their peculiar characters were entirely unknown not many years ago; the whole group being then supposed by geologists to belong to a series of marine clays and sands below the chalk.*

Before entering upon the description of these strata, I

oolitic period; assigning the Wealden proper to the cretaceous age. In this Sir C. Lyell has followed him.

In Germany, Purbeckian and Wealden fossils appear to occur together; Brown, Roemer, and others referring them to the Oolitic series. There still remains a wide field for research in the study of the extent and relations of these and other fluvio-marine deposits of the mesozoic period.

For a *résumé* of geological memoirs on the Wealden, the student is referred to that great storehouse of information, M. D'Archiac's "Histoire des Progrès de la Géologie, vol. iv.

* "Until the appearance of Mr. Mantell's works on the geology of Sussex, the peculiar relations of the vast thickness of sandstones and clays of the interior of Kent, Sussex, and Hampshire were entirely misunderstood. No one supposed that these immense strata were altogether of a peculiar type, and interpolated amidst the rest of the marine formations, as a local estuary formation, of which only very faint traces can be perceived in other parts of England."—*Professor John Phillips, Ency. Metropolitana*, p. 631, Art. *Geology;* and *Manual of Geology*, 1856, p. 313. See also *Dr. Fitton's Geology of Hastings*, p. 14.

would remind you of the effects of rivers, and the nature of modern fluviatile deposits, as explained in a previous Lecture (p. 56). We found the deltas of rivers to consist of clay (or indurated mud), alternating with beds of sand and sandstone (or consolidated sand), and containing leaves, branches, and trunks of trees, fresh-water shells, works of art, bones of man and of land-animals, more or less rolled, together with boulders formed of fragments of rocks, transported by torrents from the hills, or washed out of the banks by the streams.

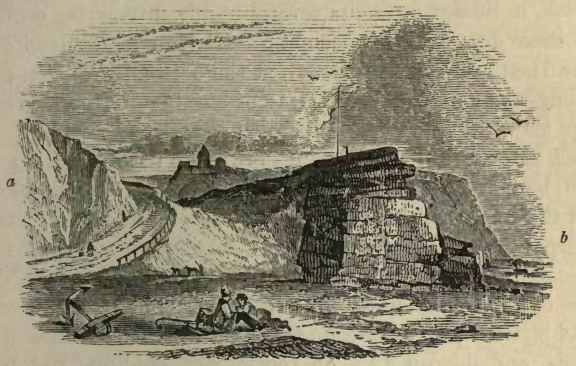
Let us now suppose that, by agencies already explained, a river has disappeared, that the sea also has changed its place, and that the bed of the river and the delta have become dry land; that towns and villages have been built upon the consolidated fluviatile sediments, and that the surface is either clothed with turf or forests, or under cultivation. If sections of the strata were exposed, either by natural or artificial means, and the bones of men and animals, with works of art, and remains of plants and shells, were visible in the clay or sandstone, such appearances would excite in us no surprise, because we have made ourselves acquainted with the process by which such deposits are accumulated. And should an inhabitant of the new country express his wonder how brittle shells and delicate leaves and bones had become imbedded in the solid rock,—and if, when we stated the manner in which those changes had been effected, he should not only refuse his assent to our explanation, but insist that the shells, leaves, and bones were merely accidental forms of the stone, should we not feel astonished at his ignorance and prejudice?—yet not a century since, and such an opinion almost universally prevailed, and is even still entertained by many. And further, if our assumed personage admitted that the remains in question were fossil animals and vegetables, but asserted that they had been entombed in the strata by a general deluge which had softened the crust of

the earth, and ingulfed in the sediments of its waters the remains of animated nature,—should we not reply, that, as such a catastrophe must inevitably have mingled together the relics of animals and vegetables, whether of the land, the rivers, or the seas, the regular stratification of the materials composing the delta, and the exclusive occurrence of land and fresh-water productions, were fatal to such a supposition, and afforded conclusive evidence of the correctness of our explanation of the phenomena? It was by such inductions that the fluviatile nature of the Wealden was established.

5. WEALDEN OF THE SUSSEX COAST.—From the extensive exposure of the Wealden in the south-east of England, instructive sections have been formed between Beachy Head and Dover by the action of the sea along the coast. From the stupendous cliffs of Beachy Head, the Chalk extends towards Southbourn, where beds of Gault and of Upper and Lower Greensand successively emerge, forming the base of the shore, and abounding in characteristic marine fossils. Passing over Pevensey Levels, the boundary of which on the sea-side is obscured by modern shingle, we arrive at Bexhill and Bulverhithe, and find the cliffs composed of laminated sandstones and clays; and those of St. Leonard's, of similar strata, more extensively developed: sands and clays separated into very thin laminæ alternate with conglomerates, indurated sand-rock, and gritty sandstones. At Hastings, sands and clays, with interspersions of lignite, laminated shales, grits, and sandstones, constitute a long range of high cliffs.* The general resemblance of these

* See A Guide to the Geology of Hastings; by W. H. Fitton, M.D., F.R.S., &c. The "Geology of the South-east of England" contains a map, sections, and details of the geological structure of this interesting district. Mr. Webster's memoir in the Geological Transactions, and Mr. Beckles's later observations in the Quarterly Geolog. Journal, illustrate with great minuteness the stratification of the Hastings cliffs.

strata to fluviatile sediments is most striking; the laminated structure of the clays and shales, the constant intermixture of minute portions of lignite, the absence of pebbles and shingle, and the alternations of mud and sand, are lithological characters constantly observable in river-deposits.



LIGN. 86.—WHITE ROCK, HASTINGS; SEEN FROM THE SOUTH-WEST, AS IT EXISTED SOME YEARS SINCE.

(Drawn by Miss Jane Allnutt.)

a, Inland cliff of laminated sandstone and clay. *b*, Cliff to the east of Hastings. The White Rock is marked by the flag on its summit; it was composed of calciferous grit.

To the west of Hastings a fine mass of the strata, comprising several layers of calciferous grit, alternating with friable sandstone, was formerly exposed on the sea-shore; having at a very remote period been separated from the adjacent cliff. The action of the waves having bleached the projecting layers of grit, the mass obtained the local name of "*White Rock*" (*Lign.* 86); but the late improvements between Hastings and St. Leonard's have removed all traces of this outlying portion of the Hastings beds. The nature of the organic remains which the strata contain will be considered hereafter.

6. POUNCEFORD.—In the interior of the country, the quarries opened along the ridges formed by the compact grit afford various instructive sections; and the valleys which are eroded by streams expose in many places the beds of shales, laminated clays, and limestones. Pounceford, on the estate of the Earl of Ashburnham, on the road to Burwash, in Sussex, presents several highly interesting sections of these deposits.* Descending through a defile cut through the Hastings sands, we arrive at the bottom of a deep glen, along which a rapid stream, that bursts out from between the clay-partings, rushes to a distant and lower valley. On each side of the vale, openings are made to arrive at a greyish blue limestone, abounding in shells, which is employed on the roads, and is also converted into lime for agricultural purposes. Where the stone lies deep, shafts are sunk from the surface, and after the extraction of the limestone they are deserted and filled up. This spot is highly interesting and picturesque; incrusting springs issue from the limestone-beds, and deposit tufa on the mosses, equiseta, and land-shells. Thousands of fossil shells are seen in the clays and shales; and stems of plants, scales of fishes, teeth and bones of reptiles, and other remains are imbedded in the stone; while the banks, where newly exposed, exhibit numberless alternations of laminated shales and clays, full of fresh-water shells. In a visit to this place with Sir C. Lyell, in 1831, many new species of shells were found in the bed of the stream, having been washed out of the banks of clay; and we collected teeth of crocodiles, and bones of fresh-water turtles and of other reptiles. Several species of *Cyclas* or *Cyrena* and of *Cerithium* were abundant in the clay (*Lign.* 103); and a mussel-shell, which has been named *Mytilus Lyellii*, to commemorate our excursion, also an estuarine species, was found in a mass of shale that had fallen into the rivulet.

* Geology of the South-east of England, p. 222.

7. Tilgate Forest.—As the grit or calciferous sandstone of this district forms an excellent road-material, the quarries along the principal lines of road leading from the metropolis to the south-eastern coast are very numerous; and those spread over the area of Tilgate and St. Leonard's Forests were extensively worked some twenty-five years since, when an increased communication between London and Brighton rendered it alike necessary and profitable to keep the turnpike-roads in the best possible state.

This district may be described as bounded on the west by the London-roads leading through Horsham, and on the east by those which pass by Lindfield and Cuckfield;* the Crawley-road, as previously mentioned, passing through Tilgate Forest. These localities, particularly the latter, have acquired much celebrity for their organic remains; the quarries in that part of Sussex having been the principal source whence the specimens figured in my work on the "*Fossils of Tilgate Forest*"† were derived; but every quarry throughout the Forest-range, from Loxwood, in western Sussex, to Hastings, have yielded the peculiar fossils of the Wealden, more or less abundantly.

The quarries around Tilgate Forest, where the calciferous grit is worked, present the following section:—

1. *Uppermost.* Loam or clay from one to five or six feet in depth; destitute of fossils.
2. Sandstone of various shades of fawn, yellow, and rusty colour, in laminæ or thin layers, occasionally containing organic remains and pebbles; ‡ eight feet thick.

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* For a sketch of the Cuckfield Quarries, see Petrif. and their Teachings, p. 202; and frontispiece to Geology of S.E. England.

† The Fossils of Tilgate Forest, 1 vol. 4to, with plates, 1827.

‡ The pebbles found in the Wealden beds of Sussex and the Isle of Wight are but small. The equivalent strata at Swanage Bay contain rather coarser pebbles, according to the Rev. O. Fisher; who further states that at Worbarrow Bay and at Lulworth, as also at Ridgway, the

3. Sandstone, with concretionary masses of harder sandstone and grit. This hard sandstone is formed of sand cemented together by calcareous spar; hence, when broken, it presents glistening specks over the fractured surface, giving it a chatoyant lustre. This sandstone or grit has evidently been formed by the percolation of water charged with calcareous matter into loose sand; it abounds in bones and teeth of reptiles, stems and leaves of plants, shells, &c. Towards its base the *Tilgate grit* contains thin layers of conglomerate, formed of rolled pebbles of sandstone, jasper, quartz, indurated clay, bones and teeth of reptiles, and of fishes; these organic remains are generally much waterworn.
4. Blue clay, with bones and fresh-water shells; depth unknown.

This is the usual series of strata exposed in the quarries around Cuckfield, Lindfield, Bolney, &c. Near Horsham the fawn-coloured sandstone is more compact, and of a laminated structure. The thin slabs are used for roofing, and the thicker ones for pavements; their surfaces are sometimes deeply furrowed or rippled,—an appearance upon which I will here offer a few observations.

8. RIPPLE-MARKS ON SANDSTONE.—The furrowed surface of the sandstones and grits which are used for paving in Horsham, Crawley, and other towns and villages on the Forest-ridge, must have attracted the attention of most persons who have travelled by road from Brighton to London. The appearance of these slabs is similar to that presented by the sand along the sea-shore at low water, when the ripples occasioned by the receding waves have been deeply impressed; the markings on the stone have arisen from a similar cause. In many instances the surface is so rough, that the stone is employed in stable-yards, where an uneven floor is required to prevent the feet of animals from

pebbles are coarser still. See Mr. Fisher's interesting paper on the Purbeck strata of Dorsetshire, Cambridge Phil. Soc. Transactions, vol. ix., 1855. This author's observations on the probable direction of the Wealden river (from west to east) is not discordant with Mr. Austen's views of the structure of the Wealden, Geological Society's Journal, vol. xii. p. 67.

slipping in passing over. It sometimes happens, when a large area of a quarry is cleared from the soil which covers it, that a most interesting appearance is presented, the whole surface being rippled over like the sand on the sea-shore; and the spectator is struck with the conviction, that he is standing on the sands of some ancient river-side or sea-shore, delta, lake, or estuary, now turned into stone. Sometimes the furrows are deep, showing that the water was much agitated, and the ripple strong; in other instances the undulations are gentle, and intersected by cross ripples, proving a change in the direction of the waves. Some slabs are covered by slightly elevated longitudinal ridges of sand, made up of gentle risings, disposed in a crescent-like manner; these have been produced by the rills which flowed back into the sea or river at low water. In other examples the surface is marked by angular ridges irregularly crossing each other, like the fissures in septaria; these have obviously been caused by deposition of mud or sand into crevices produced in a sandy or muddy surface by desiccation. Many slabs of stone, the smooth as well as the furrowed varieties, are covered with small subcylindrical markings, which are the trails formed by annelids (worms) or molluscs (shell-fish); but I have searched in vain for the foot-marks of turtles or other reptiles, whose bones are so abundant in these strata. The frequent occurrence of impressions of the feet of animals on the rippled sandstone of other formations renders it probable, that sooner or later the tracks of some of the oviparous quadrupeds of the Wealden will be discovered on the slabs of Tilgate stone.* The deepest furrows

* This well-founded anticipation has not been without its fulfilment. Some peculiar trifid stones, distantly representing three enormous toes of a great bird's foot united by a heel, were long ago noticed on the Wealden shores of the Isle of Wight by the Rev. Mr. Taggart, and subsequently made the subject of research by Mr. Beckles. At first these

have generally a slight coating of bluish clay, charged with minute portions of lignite and other vegetable matter; an appearance probably caused by the streams from the shore, that flowed over and coated the rippled sand. The phenomena here noticed afford an interesting example of the perfect similarity of a natural process in periods separated from each other by immense intervals of time.*

9. SUBDIVISIONS AND EXTENT OF THE WEALDEN.—The Wealden is subdivided into several groups, which are characterized by the lithological nature of the strata and the prevalence of certain kinds of fossils: throughout the whole,

fossils were thought by many to be purely concretionary in their origin; but Mr. Beckles, finding many of them on the shore near Hastings, traced them to their original places in the cliff, and found that they were thickened masses in a calcareous sandstone overlying a clay-bed, and that, as the sea washed away the clay, the trifid masses separated by their weight from the bed of which they formed part, and fell to the beach. Further, Mr. Beckles discovered that they uniformly projected on the *under* surface of the sandstone-layer, and necessarily filled cavities on the *upper* surface of the bed of clay; lastly, after some time and much labour, he discovered that both these large trifid masses and smaller trifid or three-toed *imprints* on clay-rocks of the same series of deposits (namely, the *Hasting Sands*, the group that comprises the Tilgate-stone) occurred in regular linear series. See Quart. Journ. Geol. Soc. vol. x. p. 456. From their peculiar uniserial or one-lined arrangement, Mr. Beckles was much inclined to refer these foot-prints to some unknown gigantic birds, but, in his paper on the subject, he pointed out that uniserial foot-tracks are made by some quadrupeds, both mammalian and reptilian. The late discovery, by the same indefatigable geologist, of the bones of the foot of an Iguanodon, in the Isle of Wight, will probably soon elucidate the relations of these foot-prints to their originators. A unique, but very fine, example of foot-prints similar to those above referred to is preserved at the Geological Society in a slab of *Purbeck* rock.

* For a particular account of the Wealden strata in the south-east of England, see the Geology of the South-east of England; Fossils of Tilgate Forest; Geological Excursions round the Isle of Wight, p. 192, &c.; and Petrifactions and their Teachings, p. 203.

the fluviatile or lacustrine character of the formation is maintained; in the uppermost and lowermost parts of the series only are there any intercalations of a marine or estuary nature.

Although it is not within the scope of these lectures to enter upon details of stratification, it is necessary to point out the principal subdivisions of this extensive system of fresh-water and estuarine deposits, as developed in the South and South-east of England; comprising Kent and Sussex, the Isle of Wight, and the Isle of Purbeck.

- **Wealden Formation.**
  - **Wealden proper.**
    - **Weald clay.** — Stiff blue clay, with argillaceous ironstones, and beds of shelly limestone called *Sussex, Petworth,* or *Bethersden marble.*
    - **Hastings Sands.** — Sands and sandstones. *Horsham beds.* Sandstone and grit. *Tilgate stone.* Sand, sandstone, and clay. *Worth beds.* Shelly limestone, shales, sandstones, and clay. *Ashburnham beds.*
  - **Purbeck Beds.** — Shales, shelly limestones, with chert, in the lower beds. The paludina-limestones of the upper part of this series supply the *Purbeck marble.* At the base of the series is a fresh-water limestone (resting on the *Portland stone*), with layers of *vegetable mould,* and trunks of trees in a vertical position—the *petrified forest of Portland.*

Such is the assemblage of deposits to which the term Wealden, first employed in this acceptation by Mr. Martin,* is geologically applied. Clays with layers of limestones almost wholly composed of fresh-water univalves, or of small bivalves, with carapaces of minute crustaceans, form the upper series (*Weald clay*). Sand and sandstone, with bands of calciferous sandstones, conglomerate, shales, with bands of argillaceous ironstone,† grit, and irregular interspersions

* Geology of Western Sussex, by J. P. Martin, Esq.

† The layers and bands of ironstone that occur interspersed with the

of lignite, together with sands, clays, and argillaceous shelly limestones, compose the middle group (*Hastings beds*). Another (the *Purbeck*) series of shaly clays and shelly limestones succeed; and buried in the base of these, is a petrified pine-forest, with cycadeous plants; the trees still erect in the soil in which they grew! And in nearly all these deposits, bones of reptiles are more or less abundant; whilst in the upper part of the series (or Wealden proper) the remains of the colossal terrestrial reptiles are not unfrequent.

The Weald clay and its limestones, &c., occupy the valleys of the Wealden districts that skirt the inner escarpments of the chalk-downs in Surrey, Kent, and Sussex; the upper portion of the Tilgate and Hastings group of sands and sandstones constitutes the Forest Ridge of those counties; and its lower portion appears in the deep valleys in the east of Sussex, around Battle, Brightling, Burwash, and Ashburnham.

The Purbeck strata, the upper portion of which is characterized by thick beds of shelly limestone principally formed of one small species of paludina, appear on the coast of Dorsetshire, in the island, or more properly the peninsula, whose

argillaceous and arenaceous Wealden deposits, were formerly the source of the principal iron-manufactures of this country, the iron-works of Sussex especially were in full activity in the time of Henry VIII. and Queen Elizabeth. (See Hist. of Sussex, Dallaways and Horsfield's.) The use of coal in Wales and the north of England, and the scarcity of wood in the Wealden districts, occasioned the total decline of the iron-manufactures of the S. E. of England. The last forge was worked at Penhurst, near Ashburnham, during the commencement of the present century (1848).

Indications of an iron-work of the Romans have been discovered by Mr. Mark Anthony Lower, near Maresfield. The Hastings sands and clays of the forest ridge appear to have been the strata principally worked. There were iron-works at Brede, Battel, Ashburnham, Mayfield, Burwash, Wadhurst, Lamberhurst, Buxted, Chiddingly, Heathfield, Cuckfield, Worth, Ifield, Tilgate Forest, to Farnhurst, on the borders of Hampshire.

name they bear. These Purbeck deposits range along the southern shore of the Isle of Purbeck, and their lowermost beds crest the northern brow of the Isle of Portland, overlying the oolitic limestones of which that insular mass of strata is chiefly composed.

The Purbeck beds also occur in the vale of Wardour, which is a valley of denudation in the south of Wiltshire, representing on a small scale that of the Wealden in the south-east of England. In this valley the various members of the chalk-series occur in their regular order of superposition, resting on clay and Purbeck limestone, and having the Portland-stone beneath.*

Near Hartwell and at Stone in Buckinghamshire, and Swindon † in Wiltshire, the oolite is capped by layers of fresh-water and estuarine limestones and marls of the Purbeck series.

In France, on the coast of the Lower Boulonnais, and in the valley of Bray near Beauvais, strata of a like character are observable, in which the Sussex marble (*lumachelle à paludines*) and a fern common in the Wealden ‡ have been discovered by M. Graves of Beauvais. There can be no doubt that this formation originally extended over a much larger area; for the Wealden deposits are extensively exposed in northern Germany, as will presently be noticed.

* Dr. Fitton, "*On the beds below the Chalk;*" Geological Transactions, 1837, p. 424. Also Mr. Brodie's paper, Geol. Journ. vol. x. p. 475.

† For the latest observations on the interesting section in the great Swindon quarry, see Mr. Austen's paper on the Farringdon district, in the Quarterly Journal of the Geol. Soc. vol. vi. p. 464.

‡ The fern (*Lonchopteris Mantelli*) has also been found in strata beneath the greensand, in Sweden, by Professor Neilson, who informed me that several of the plants from Tilgate Forest were analogous to specimens he had collected in the little island of Bornholm, off the Danish coast. See also Adolphe Brongniart's "Observations sur les Végétaux fossiles renfermés dans les grès de Hoer en Scanie; Annales des Sciences Naturelles, 1825.

If these different localities exhibit parts of a continuous extent of fresh-water deposits, as is probably the case, the Wealden may be estimated as spreading over an area of more than 200 miles in length from west to east, and 220 miles from north-west to south-east; * an extent but little exceeding the delta † of the Ganges or of the Mississippi, and surpassed by that of the Quorra, which forms a surface of 25,000 square miles, an area equal to half the superficial surface of England.‡ The total thickness of the Wealden and Purbeck deposits is estimated at 1350 feet; whilst that of the delta of the Mississippi is said to exceed 600 feet.

10. WEALDEN OF THE NORTH OF GERMANY. — In the north of Germany the Wealden formation has been traced by M. Römer § and other observers over a considerable part of Hanover, covering a large area to the north of the Porta Westphalica, including the coal-field of Bückeburg, the coaly beds of which are faintly represented by the lignite dispersed throughout some of our Wealden beds. These Wealden deposits lie upon the oolite, and beneath the lower greensand; thus occupying the same geological position as their English equivalents; the total thickness of the series is estimated at 800 feet. Numerous characteristic fossils

* See also Mr. Austen's observations on the extent of the Wealden deposits, and the probable area occupied by the Wealden estuary or lagoon, Quarterly Geological Journal, vol. xii. p. 67. In the map accompanying his memoir, Mr. Austen defines this Wealden area as the north-western extremity of a narrow gulf or inlet of the Southern Neocomian or Lower Cretaceous sea.

† See Lyell on Deltas, "Principles," 1853, p. 254, &c.

‡ Dr. Fitton.

§ Versteinerungen des Nord-deutschen Oolithen-Gebirges; by Professor Römer: Hanover, 1836. In this work Mr. Römer enumerates many fossils which distinguish the Ashburnham (*Ashburnham-schichte*), Hastings (*Hastings-sandstein*), Tilgate (*Tilgat-stein*), and Weald-clay (*Wälder-thon*) deposits. Cyprides, Paludinæ, Cyrenæ, Cyclades, &c. are mentioned as prevailing throughout the series.

occur throughout these strata; and even the principal subdivisions of the Sussex group have been distinguished.

A beautiful work on the Wealden of the north of Germany has been published by Dr. Wilhelm Dunker, in which are numerous important additions to our knowledge of the fauna and flora of the country whence the Wealden deposits were derived. It contains figures and descriptions of nearly fifty plants, and of a still greater number of shells, several fishes, and two new reptiles; the plants are chiefly ferns and cycadeæ.*

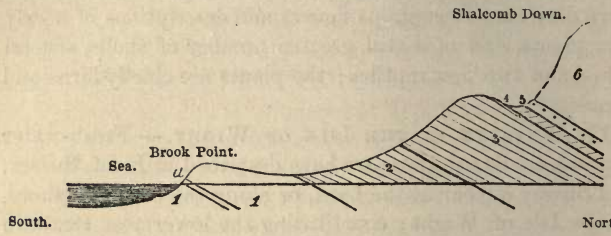
11. Wealden of the Isle of Wight. — Fresh-water deposits similar to those we have described in Kent, Sussex, and Surrey appear at the back, or along the southern shore, of the Isle of Wight; constituting the lowermost strata in that island, as shown in the section, *Lign.* 85, p. 374. These strata consist of clays, sands, and sandstones, with bands of shelly limestones and grit; and are replete with the same species of river-shells, terrestrial plants, and bones of reptiles, as those contained in the Wealden of the S. E. of England. They form a line of low cliffs in Sandown Bay, on the south-east of the island, and in the bay between Atherfield Point and Compton Bay, on the south-west.†

The relative position of the strata is shown in the annexed section, from the coast at Brook Point to the chalk-downs on the north. If we proceed from the sea-shore at Brook Chine, through the village of Brook, towards Shalcomb Down, we pass over the beds in the following order. 1. Wealden clays, grits, &c., forming the cliff. 2. and 3. Lower Greensand. 4. Gault. 5. Upper Greensand. 6. Chalk.

* Monographie der Nord-deutschen Wealdenbildung. Ein Beitrag zur Geognosie und Naturgeschichte der Vorwelt. Von Dr. Wilhelm Dunker. Brunswick, 1846. One vol. 4to, with 21 plates.

† The reader is referred to my Geological Excursions round the Isle of Wight, for particular information on these strata and their organic remains.

The Wealden beds form the entire cliff for several miles along this part of the coast; but they may be seen dipping under the lowermost sands of the cretaceous formation, near Compton Chine on the west of Brook Bay, and near Atherfield Point on the east. Most of the peculiar fossils of the



LIGN. 87.—SECTION FROM BROOK POINT TO SHALCOMB DOWN; IN THE ISLE OF WIGHT.

1. Wealden beds. *a*. Fossil Trees. 2. Lower group of Lower Greensand. 3. Upper group of Lower Greensand. 4. Gault. 5. Upper Greensand. 6. White Chalk.

Wealden have been obtained from these shores; quantities of bones of enormous reptiles, fresh-water shells, and minute crustaceans in immense quantities, river-mussels of large size, and ferns and cycadeous plants. But the most remarkable phenomenon at Brook Point is the occurrence, at the foot of the cliff, of a prostrate forest of petrified pine-trees.

12. FOSSIL TREES OF THE WEALDEN, AT BROOK POINT.—The cliff at Brook Point is between thirty and forty feet high, and is capped by a thick bed of alluvial gravel and loam. It is composed of layers of clay and shale finely laminated, with thin seams and masses of lignite. The lower part of the cliff consists of beds of hard sandstone and grit, resting upon mottled clays and sands, which are the lowermost Wealden strata in the island. The fossil trees are imbedded in the sandstone, and protrude from the water-worn edges of the rock. This indurated grit forms a sort of buttress at the foot of the cliff, having resisted the tidal

action which has carried away the upper and less coherent deposits: the numerous reefs that appear off the shore at low water, and render this coast so dangerous to mariners, have also originated from this cause.

The trees are lying confusedly one upon another. There are no erect trunks, nor any other indications that the forest was submerged while growing in its native soil, like that of the Isle of Portland; on the contrary, the appearance both of the trunks in the sand-rock, and of those exposed to view by the removal of the materials in which they were originally imbedded, is that presented by the rafts of trees that float down the great rivers of America; as for example the Ohio and Mississippi. Such rafts entangle in their course the remains of animals and plants that may happen to lie in the bed of the river, and at length subside and are ingulfed in silt and sand; in like manner the fossil trees in this cliff are associated with river-shells (*Uniones*) and bones of land-reptiles. The fossil forest at Brook Point is, in fact, a raft of pine-trees, which floated down the river that deposited the Wealden beds, and was submerged in its delta, burying with it bones of terrestrial animals, shells of fresh-water mussels, &c.

The trees when lying in the sandstone are invariably covered with their bark, now in the state of lignite; it varies from one to three or four inches in thickness, according to the magnitude of the trunk. This carbonized cortical investment is quickly removed on exposure to the action of the waves; but the ligneous structure, the woody fibre, remains. The trees are calcareous, not siliceous like those of Portland; they are more or less traversed by pyrites, and the delicate veins and filaments of this mineral which permeate the woody fibre impart a beautiful appearance to polished specimens. The trunks are generally of considerable magnitude, being from one to three feet in diameter; some are of such a size as to indicate a height of forty or

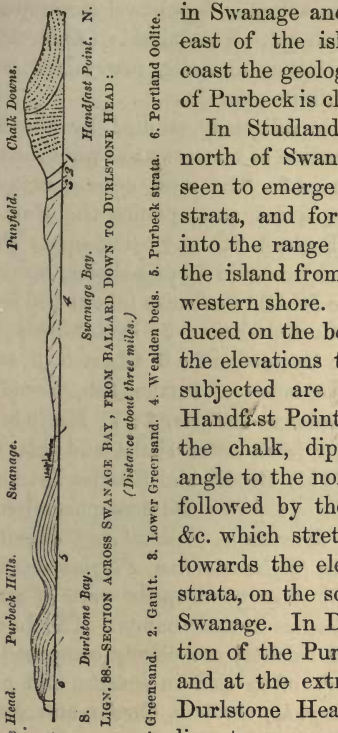
fifty feet when entire. In the conversion of the bark into lignite, and in the smooth condition of the trunks, the trees of this fossil forest present a remarkable dissimilarity from those of the Isle of Portland, which we shall presently examine; for in the latter the carbonized bark rarely, if ever, occurs, and the surface of the stems is similar to that exhibited by the trunks of old decorticated trees, that have been much weathered by alternate exposure to air and moisture. At Brook Point, on the other hand, the trees appear to have been ingulfed when fresh and vigorous, with their bark and vessels full of sap. The annular lines of growth are often very distinct, and I have traced from thirty to forty on some of the stems; but these circles are unequal, and indicate therefore a variation from year to year in the climate of the country in which they grew. The wood exhibits, under the microscope, the coniferous structure seen in the *Araucaria* (Norfolk Island Pine), the rows of glands or ducts being placed alternately; and the appearance is similar to that of the fossil wood of Willingdon in Sussex.* Obscure traces of the foliage of these trees, and several specimens of cones, in the state of pyrites, and evidently associated with the trees of the fossil forest of Brook Point, have been met with.† In the strata that overlie the fossil forest, thin interrupted seams and irregular masses of lignite, more or less impregnated with and permeated by iron-pyrites, are very abundant.

13. WEALDEN OF THE ISLE OF PURBECK.—The Wealden deposits are next seen in the Isle of Purbeck, the south-eastern part of Dorsetshire, which is distant about fifteen miles across the Channel, from the western extremity of the Isle of Wight. This island or peninsula is an irregular oval area, between thirteen and fourteen miles in length,

* Medals of Creation, vol. i. p. 173.

† Excursions round the Isle of Wight, p. 327; and Medals, vol. i. p. 176.

and seven in average breadth from north to south. It consists of cretaceous, Wealden, Purbeck, and oolitic strata, which occur in their natural order of succession, but highly inclined, in the section exposed in Swanage and Durlstone Bays, on the east of the island.* In this line of coast the geological structure of the Isle of Purbeck is clearly displayed.



LIGN. 88.—SECTION ACROSS SWANAGE BAY, FROM BALLARD DOWN TO DURLSTONE HEAD:
(Distance about three miles.)

In Studland Bay, which is to the north of Swanage, the white chalk is seen to emerge from beneath the eocene strata, and form the cliffs; rising up into the range of downs that traverses the island from the east to the south-western shore. The curious flexures produced on the beds of chalk and flint by the elevations to which they have been subjected are remarkably distinct at Handfast Point. The lower divisions of the chalk, dipping at a considerable angle to the north, next appear, and are followed by the Wealden clays, sands, &c. which stretch along Swanage Bay, towards the elevated ridge of Purbeck strata, on the south of the little town of Swanage. In Durlstone Bay a fine section of the Purbeck beds is exposed; † and at the extreme point, just beyond Durlstone Head, the Portland oolitic limestone appears. Purbeck has long been celebrated for its quarries, which have been worked from time immemorial, and particularly during the middle

* Geology of the Isle of Wight, p. 252.

† A sectional list of the beds exposed in the cliffs of this Bay has been

ages; the compact varieties of the limestone, which take a good polish, having, under the name of Purbeck marble, been in great request for the religious edifices of that period; and there is scarcely a cathedral or ancient church in England that does not contain columns, sepulchral monuments, or pavements, of this material. This marble (*Lign.* 102) is a congeries of small river-snail-shells, intermixed with the crustaceous cases of minute cypridæ.

The Purbeck beds were diligently studied by the late Prof. E. Forbes, and an outline of his views was published in the New Edinburgh Journal.* The most correct detailed list of the strata of this series accompanies the Rev. O. Fisher's Memoir on the Purbeck Strata.† The upper Purbecks (about 20 feet thick) contain Cypris-shales, Marble-bands, and Unio-beds; the Middle Purbecks (about 160 feet) have, 1. Shelly-beds, 2. Corbula-beds; 3. Pecten-beds; 4. Turtle-beds; 5. Cinder or Oyster-band; 6. Chert-beds, with Cypridæ, Planorbis, Cyclas, bones of turtles, fish, crocodile, and the little reptilian *Nuthetes destructor* ‡; 7. Marly beds, containing Unio and other fresh-water shells, and comprising a thin bed in which MM. Brodie and Beckles have discovered numerous remains of reptiles and mammals of small size.§ The reptiles are *Macellodus Brodiei* and *Saurillus obtusus;* the mammals are *Spalacotherium*, *Plagiaulax*, *Triconodon*, and others. All these quadrupeds were of small size, and probably insectivorous in their habits. The Lower Purbecks (about 160 feet thicker) are chiefly composed of marls and limestones, very often rich in insects, and containing here and there *Serpulæ*, *Cerithia*, *Cardia*, and *Ento-*

published by the Rev. Mr. Austen, in a little pamphlet entitled A Guide to the Geology of Purbeck, &c. 1852.

* See also Lyell's Manual of Geology, 1855, p. 294, &c.

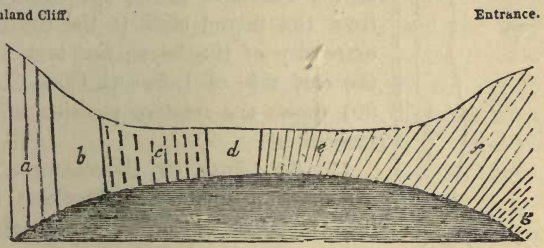
† Transact. Cambridge Phil. Soc. vol. ix. 1855.

‡ Quart. Journ. Geol. Soc. vol. x. p. 420.

§ Ibid. p. 422; and Proceed. for March, 1857. Lyell's Manual, Supplement, 1857.

mostraca, underlaid by beds often made up of Cypridæ, associated with Valvata, Limnæa, remains of small fishes, and vegetable fragments.* The "Portland dirt-bed" is intercalated in the lower part of this division.

14. COVES IN THE SOUTH-WEST OF THE ISLE OF PURBECK.—On the south-west coast of the Isle of Purbeck, the range of vertical chalk-strata, the eastern extremity of which forms the high cliffs at Handfast Point (*Lign.* 88), reappears in several coves or inland recesses, which have been formed by the inroads of the sea; no less than nine sections of the strata, from the chalk to the oolite inclusive, being exposed along this coast, within a distance of five miles.† The subjoined diagram (*Lign.* 89) will explain the geological structure of these bays.



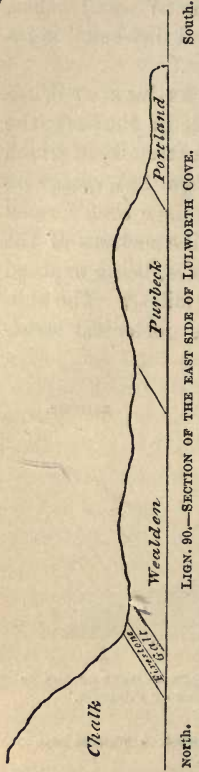
LIGN. 89.—DIAGRAM OF THE STRUCTURE OF THE INNER FACE OF HALF OF ONE OF THE COVES ON THE SOUTH-WEST COAST OF THE ISLE OF PURBECK.

a, Chalk. *b*, Upper Greensand. *c*, Gault. *d*, Lower Greensand. *e*, Wealden beds. *f*, Purbeck beds. *g*, Portland stone.

The northern barrier of the coves consists of precipitous chalk-cliffs; the entrance is formed by rocks of Portland

* This portion of the series is best studied in the sections at Ridgway, both on the railway and in the neighbouring quarries. A list of the strata, as seen at Ridgway, forms part of Mr. Fisher's lucid and valuable memoir above referred to.

† Geol. Exc. Isle of Wight, p. 266.



LIGN. 90.—SECTION OF THE EAST SIDE OF LULWORTH COVE.

and Purbeck limestone; and between them is a low tract composed of the less durable Wealden strata. These bays expose, in fact, transverse sections of the range of hills formed by the Portland and Purbeck beds, and of the clays, sands, &c. of the Wealden, and, at their back, precipices of great height, produced by the destruction of the southern face of the vertical chalk of the Downs.*

Thus, within the distance of six or seven hundred yards, we may examine the entire series of strata from the chalk to the Portland oolite, by proceeding from the inland cliffs to the southern extremity of the bays; the section of the east side of Lulworth Cove (*Lign.* 90) shows the relative position of the formations.

15. THE ISLE OF PORTLAND.—The island, or peninsula, of Portland is a bold headland, off Weymouth, about four miles and a half in length, two in breadth, and 300 feet high; it is united to the mainland by a bank of shingle called the Chesil Beach. Portland presents on the north a precipitous escarpment; and, declining towards the south, appears, on approaching it from the east or west, like

* An excellent section of the Wealden and Purbeck beds is also exhibited by the railway-cutting through the Ridgway Hill between Dorchester and Weymouth. See Mr. Weston's descriptions of this section, Quart. Journ. Geol. Soc. vol. iv. p. 215, 245, and vol. viii. p. 110; and Mr. Fisher's paper in the Cambridge Transactions, 1855.

an insulated inclined plane, rising abruptly from the sea. The southern extremity is flanked by low calcareous cliffs, which, from the constant action of the sea, are worn into hollows and caverns. The base of the island is formed of a blue clay (*Kimmeridge clay*), surmounted by beds of sand (*Portland sand*); and on these are superimposed thick strata of the oolitic limestone, known as the *Portland stone*, which is extensively quarried in the northern brow of the island.

The strata dip to the south at an angle which corresponds with the profile of the island. The coasts are steep, the base of Kimmeridge clay forming a talus, surmounted by perpendicular crags of oolite. The southern extremity consists of low oolitic limestone cliffs, which are worn into numerous caverns by the force of the waves.

The northern brow of the island, to a depth of upwards of twenty feet, is formed of finely laminated fresh-water limestone, locally termed "*The Cap*," which belongs to the Purbeck series, and is superimposed on the uppermost bed of oolite. The Kimmeridge clay, which is the lowest visible deposit in the island, contains the usual marine shells, &c. that prevail in this bed in the Isle of Purbeck * and other parts of England. The oolitic limestone, which lies immediately upon the sand overlying the clay, contains nodules and veins of flint and chert. It abounds with remains of marine shell-fish, peculiar to the oolite; and its upper portion, to within twenty feet of the surface, consists of the fine architectural stone which is locally termed the *white-bed*. Upon this is a stratum, three or four feet thick, of limestone, full of cavities left by the decomposition of numerous shells, of which the casts only remain (chiefly Terebra, Trigonia, and Cardium); and above is an irregular layer of flint-nodules,

* Geol. Exc. Isle of Wight, p. 261, 287, and pref. note, p. xxi.

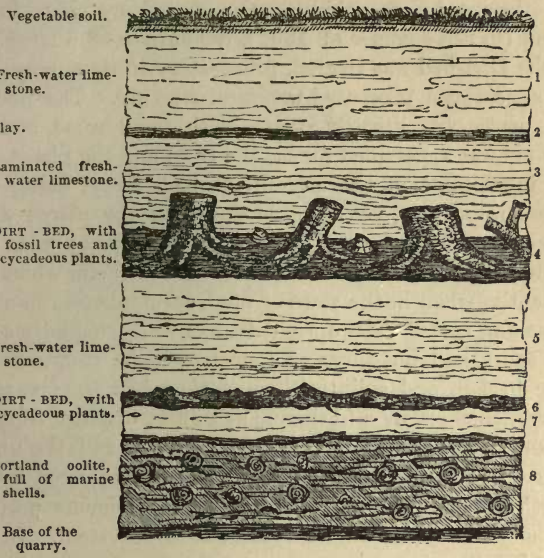
in coarse oolite, which in some places passes imperceptibly into the fresh-water limestone of the Purbeck series.*

16. THE PETRIFIED FOREST OF PORTLAND.—The fresh-water strata which form the northern brow of the Isle of Portland belong to the lowermost beds of the Purbeck group of the Wealden formation. They are in fact the first sediments that were deposited by the body of fresh water which covered for ages the ancient oolitic rocks; and they indicate the commencement of the delta which ultimately spread over a great part of England and northern Germany; they are therefore, in every point of view, in the highest degree interesting. The annexed section of a quarry (*Lign.* 91) in which these strata are seen in their natural position will serve to exemplify the following remarks.

The lowermost beds in this quarry consist of the Portland building-stone (8), and upon these are layers of rubbly oolite (7), covered by a thin seam of black earth (6), with interspersed vegetable matter, in which fossil cycadeous plants, closely allied to Zamiæ, have been discovered. This is succeeded by laminated fresh-water limestone (5), upon which is the remarkable stratum called "*Dirt-bed*" (4) by the quarrymen. This bed is about one foot in thickness, and consists of a dark-brown friable loam, containing a large proportion of earthy lignite, and, like the modern soil of the island, many water-worn stones and pebbles. This stratum appears to have been a bed of vegetable mould which supported a luxuriant flora; for in and upon it are numerous trunks and branches of coniferous trees and remains of cycadeous plants. Above the dirt-bed are finely laminated cream-coloured limestones (3, 2, 1), the total thickness of which is about ten feet; in these beds a few cypridæ are the only organic remains that have been observed. These

* See Mr. Weston's description and section, Quart. Journ. Geol. Soc. vol. viii. p. 117.

limestones are covered by the modern vegetable soil, which but little exceeds in depth the ancient one, above mention-



LIGN. 91.—SECTION OF A QUARRY IN THE ISLE OF PORTLAND.*

ed, and, instead of supporting cycadeous plants and pine-forests, barely maintains a scanty vegetation, there being but few trees or shrubs in the whole island.

But the most remarkable fact which this section presents, is the position of the trees and plants in the Dirt-bed; for they are still erect, as if they had been petrified while growing in their native forests, with their roots in the vegetable soil, and their trunks extending into the limestone

* From Dr. Fitton's Memoir on the strata below the Chalk. Geological Trans. 2nd series, vol. iv.

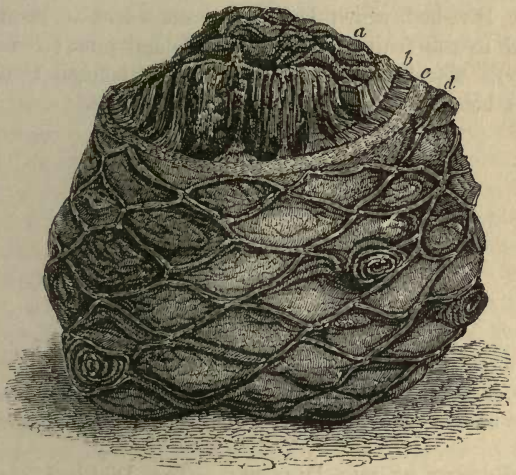
above (*Lign.* 91, 4, 3,). As the Portland building-stone lies beneath the fresh-water strata, which are but little employed for economical purposes, the petrified trees are removed, and thrown by as rubbish. On one of my visits to the island (in the summer of 1832), the surface of a large area of the Dirt-bed was cleared, preparatory to its removal, and the appearance presented was most striking. The floor of the quarry was literally strewn with fossil wood, and before me was a petrified forest, the trees and the plants, like the inhabitants of the city in Arabian story, being converted into stone, yet still remaining in the places which they occupied when alive! Some of the trunks were surrounded by a conical mound of calcareous earth, which had evidently, when in the state of mud, accumulated round the stems and roots. The upright trunks were generally a few feet apart, and but three or four feet high; their summits were broken and splintered, as if they had been snapped or wrenched off by a hurricane at a short distance from the ground. Some were two feet in diameter, and the united fragments of one of the prostrate trunks indicated a total length of from 30 to 40 feet; in many specimens portions of the branches remained attached to the stem. In the *Dirt-bed*, there were numerous trunks lying prostrate, and fragments of branches.

The external surface of all the trees I examined was weather-worn, and resembled that of posts and timbers of groins or piers within reach of the tides, and subjected to the alternate influence of the water and atmosphere; there are but seldom any vestiges of the bark.

17. FOSSIL CYCADEÆ:—MANTELLIA.—The fossil plants related to the recent *Zamia*,* a genus of the *Cycadeæ* family,

* These plants are so common in conservatories that their general appearance must be familiar to the reader. In the botanic gardens at Kew, there are magnificent specimens of Zamia and Cycas, and other plants of hot climates, forms related to which occur in the Wealden.

occur in the intervals between the pine-trees; and the dirt-bed is so little consolidated, that I dug up with a spade, as from a parterre, several specimens that were standing on the very spot where they originally grew, having, like the columns of the Temple at Puzzuoli (p. 106), preserved their



LIGN. 92.—SILICIFIED STEM OF MANTELLIA NIDIFORMIS, FROM PORTLAND, *one-fourth the natural size.*

(Cycadeoidea megalophylla, Dr. Buckland.)

a, Central mass of cellular tissue; *b*, Circle of radiating woody plates; *c*, Zone of cellular tissue; *d*, The case, or false bark.

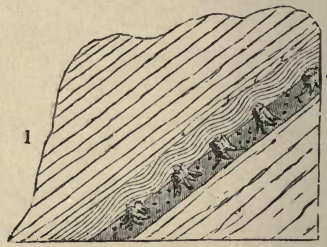
original erect position amidst all the revolutions which have subsequently swept over the surface of the earth, and buried them beneath the accumulated detritus of innumerable ages.

These fossil plants belong to the family of Cycadaceæ, and, though allied to *Zamia*, belong to a distinct genus.* There are two species; one is short and of a spheroidal form (*M.*

* Named *Cycadeoidea* by Dr. Buckland, and *Mantellia* by M. Adolphe Brongniart.

nidiformis, *Lign.* 92) ; the other is longer and subcylindrical (*M. cylindrica* * or *microphylla*).

The trees and plants are completely silicified. Their internal structure is beautifully preserved in many examples; the wood of the trees, microscopically examined, displays the organization of the Araucaria. A cone has been found in the Dirt-bed, which Dr. Brown considers to be nearly related to the fruit of the Norfolk Island pine (*Araucaria excelsa*). The Portland and Isle of Wight fossil trees appear to belong to the same species of coniferæ.



LIGN. 93.—SECTION OF PART OF THE CLIFF ON THE EAST OF LULWORTH COVE.

1, Purbeck laminated limestone; 2, Dirt-bed, with trunks of trees; 3, Oolitic limestone of Portland.

18. EXTENT OF THE DIRT-BED.—The Dirt-bed extends throughout the northern coast of the Isle of Portland,† and appears on the coast of Purbeck under circumstances of peculiar interest. In the highly inclined strata of the cliff about a furlong to the east of Lulworth Cove a considerable number of petrified trees are exposed under similar conditions with those of the Portland quarries. The lowermost strata (*Lign.* 93, 3) are the Portland oolitic limestones, full of marine shells; upon these is the Dirt-bed with fossil

* Specimens of the former species are called "*Crows' nests*" by the quarrymen; who believe them to be birds' nests, originally built by crows in the pine-trees, both having since become petrified.

† It is also traceable in the railway-cutting on the south side of Ridgway Hill, beyond Weymouth and Dorchester.

trees (2); this is covered by cream-coloured calcareous stone in thin undulated laminæ, locally termed "*soft-burr*," and above are shales and thin bands of limestone (1), belonging to the lower series of the Purbeck.

The Dirt-bed has been discovered by Dr. Buckland near Thame in Oxfordshire; and by Dr. Fitton in the Vale of Wardour. It also occurs at Swindon in Wiltshire on the top of the Portland oolite, where fossil coniferous wood is found in abundance, and where a few examples of Mantellia have been obtained. Between Stone and Hartwell in Buckinghamshire, a seam of carbonaceous earth occupies the geological position of the Portland Dirt-bed, and is covered by cream-coloured marls and limestones resembling the *Cap*, in which wings of insects and leaflets of Wealden ferns, with remains of very small fishes and bones of turtles, have been discovered.*

From what has been stated it is evident, that after the marine strata now forming the base of the Isle of Portland were deposited at the bottom of a deep sea, and had become consolidated, the bed of that ocean was elevated above the level of the waters, and constituted a coast, an island, or an archipelago, covered with pine-forests and cycadeous plants. How long this new country existed cannot be ascertained; but that it flourished for a considerable period is certain, from the number and magnitude of the petrified trees.†

* See History of Fossil Insects in the Secondary Rocks of England, by the Rev. P. B. Brodie.

† *Modern submerged Forest.*—An interesting modern example of the subsidence of a considerable tract of country clothed with forests, the trees remaining erect, although submerged beneath a river which still flows over them, is described by an American writer, and will serve to illustrate the remarks in the text. The whole district, from the Rocky Mountains on the east to the Pacific Ocean on the west, and from Queen Charlotte's Island on the north to California on the south, presents one vast tract of volcanic formation. Basalt—both columnar and in amorphous masses, veins and dykes—everywhere occurs, and craters of ex-

19. ORGANIC REMAINS IN THE WEALDEN.—The fossils of the Wealden and Purbeck consist of leaves, stems, and branches of plants, apparently of a tropical character, relics of little insectivorous mammals, bones of terrestrial reptiles, some of enormous bulk, some of dwarfish size,—all belonging to extinct genera,—and of turtles, flying reptiles, and birds, remains of fishes of several genera and species, some marine shells, and numerous fresh-water and estuarine shells and minute crustaceans.*

The bones are often broken and rolled, as if they had been transported from a distance, but sometimes the bones of a skeleton are found in an almost perfect state of preservation. They are more or less impregnated with iron, and commonly of a dark-brown colour. Those in loose sand and sandstone are often porous and friable; those in the Tilgate grit, heavy, brittle, and with the internal structure well preserved; in fractured portions imbedded in the limestone, the interstices are filled with white calcareous spar, and the can-

tinct volcanos are still visible. Elevations and dislocations of the strata have taken place on an immense scale; and successive beds of basalt, amygdaloidal trap, and breccia prove the alternation of igneous action and periods of repose. Within a few miles of the cascades of the river Columbia, and extending for a distance upwards of twenty miles, trees are seen standing in their natural position, in a depth of water from twenty to thirty feet. The trees reach to high- or fresh-water mark, which is fifteen feet above the lowest level of the tide; but they do not project beyond the freshet-rise, above which their tops are decayed and gone. In many places the trees are so numerous, that "we had to pick our way with the canoe, as through a forest. The water of the river was so clear, that the position of the trees could be distinctly seen down to their spreading roots, and they are standing as in their natural state, before the country had become submerged. Their undisturbed position proves that the subsidence must have taken place in a tranquil manner." —*Journal of an Exploring Tour beyond the Rocky Mountains*, by the Rev. Samuel Parker, A.M. New York. 1838.

* The little Entomostraca of the Wealden have been hitherto referred to the fresh-water Cypris; but it is not improbable that they were Cytheres and inhabitants of brackish waters.

cellated structure of the bones is frequently permeated by the same substance.

The fossil vegetables occur either bituminized or in the state of sandstone-casts; carbonized leaves and twigs are abundant in some of the strata, and the stems and branches are sometimes silicified.

The shells in the clays have undergone but little change, and in many examples, the epidermis and even ligament are preserved; in the limestones, the substance of the shells is converted into spathose carbonate of lime; in the sandstones, casts of the interior of the shells are often the only vestiges. With these general remarks, I pass to the consideration of the fauna and flora of the Wealden epoch.

20. Fossil vegetables.—From the abundance of carbonized vegetable remains in many of the laminated shales and clays, and the occurrence of *lignite*, or brown-coal, in masses and layers, which sometimes alternate with shales abounding in fresh-water bivalves, a striking analogy is presented to some of the divisions of the *Coal-measures;* but there are no beds of coal of any economical value in the English Wealden.* In Hanover, however, this formation contains an extensive coal-field,† which furnishes useful fuel.

But notwithstanding the prevalence of vegetable matter in the strata, specimens exhibiting the internal structure of the plants, with any tolerable distinctness, are very rare.

Ferns. — Some strata are so full of minute portions of carbonaceous matter,‡ as to present a dark mottled colour; and, upon examining the imbedded particles, they prove to be the detritus of plants, probably ground to pieces by agitation in water loaded with sand and mud. These fragmentary remains have been principally derived from two extinct

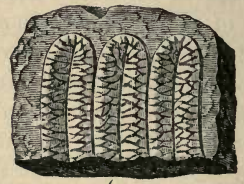
* See Geology of the South-East of England, p. xviii., and Fossils of the South Downs, p. 35, for an account of an unsuccessful trial for coal at Bexhill.

† This coal is composed of masses of bituminized fir-leaves.

‡ Fossils of Tilgate Forest, Plate 3, *fig.* 6.

species of ferns, which are common in the Wealden. The one is characterized by its slender and minutely divided wedge-shaped leaflets (*Sphenopteris Mantelli, Lign.* 94) ; the other by the long pinnated leaves and by the reticulated secondary veins or nervures that spring from the mid-rib of the leaf-lets (*Lonchopteris Mantelli, Lign.* 95). This plant has also been found fossil in the valley of Bray (p. 228), by M. Graves of Beauvais, and in Sweden, in strata the age of which has not been determined. The Lonchopteris likewise occurs in the lower greensand strata, at Atherfield and Shanklin Chine in the Isle of Wight.*

LIGN. 94.—SPHENOPTERIS MANTELLI. TILGATE FOREST.



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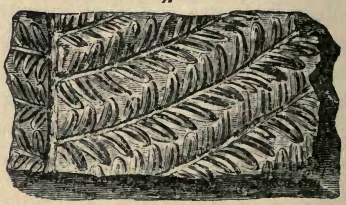
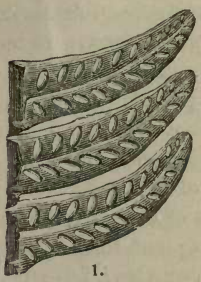


2.

LIGN. 95.—LONCHOPTERIS MANTELLI. WEALDEN CLAY; BROOK POINT.
Fig. 1. Portion of three leaflets magnified. 2. Part of stem with leaves.

* It was first noticed in this geological position by Mr. John Morris. Geol. Exc. Isle of Wight, p. 168.

These ferns probably did not attain a considerable magnitude. The largest stem of the *Sphenopteris* I have seen, probably belonged to a plant about five or six feet high. Several other species of ferns are associated with these remains; but the two plants above-named constitute by far the greatest proportion of the fossil vegetables of the Tilgate stone. There is also another fern, in which the parts of fructification are sometimes beautifully preserved (*Lign.* 96); the same species has been found in the Wealden of the north of Germany.* Obscure indications of other species of ferns occur in our Wealden clays. In the German deposits Dr. Dunker has discovered upwards of twenty species.†



1.

2

LIGN. 96.—FROND OF A FERN IN FRUCTIFICATION; IN SANDSTONE, FROM TILGATE FOREST.

(Alethopteris elegans, Dunker.)

Fig. 1. Three pinnules magnified.
Fig. 2. The specimen of the natural size.

Other plant-remains.—The stems of a species of Equisetum (*Mare's tail*) abound in the limestone-band at Pounceford.‡ Remains of the foliage of trees allied to the Cypress and Juniper have been found at Hastings and Heathfield.§ One or more species of Chara also occur in the Wealden and Purbeck.

21. CYCADEOUS PLANTS.—Leaves of cycadeous plants have been met with in the ironstone at Heathfield, Sussex, and an elegant

* Monographie der Nord-deutschen Wealdenbildung, Pl. VII. *fig.* 7.
† Ibid. p. 28.
‡ Medals of Creation, vol. i. p. 105. § Ibid. p. 180.

leaf of Pterophyllum Brongniarti was obtained several years ago from a sandstone-quarry in Surrey; and Mr. Beckles's collection is rich in fine leaves from the Hastings shales and sands. Dunker has figured and described twelve species from the Wealden of North Germany. The *Mantelliæ* of Purbeck have been already described, p. 401. Cones of a Zamia-like plant,* with fossil wood, have been found at Sandown Bay associated with bones of Iguanodon.

Endogenites erosa.†—In the strata of Tilgate Forest, in the sands of Hastings, and in the clays of Germany,‡ many specimens of the stems of a very curious plant, formerly supposed to be related to the *Euphorbia*, or *Cacti*, have been discovered. These stems are of various forms; some are subcylindrical and tapering at both ends; others are flattened and of a clavate shape. The constituent substance is a grey, compact, subcrystalline sandstone, and the external surface of the stems is traversed by fine meandering grooves and deep tubular furrows, lined with minute quartz-crystals; a transverse section exhibits the surface covered by small pores and a few large openings, the sections of the tubes. In a specimen which I picked up on the beach at Brook Point, bundles of vascular tissue are preserved; these are disposed in a flexuous zone round the margin of the stem. Judging from its structure, Dr. R. Brown thinks that this peculiar plant may have some alliances with the Cycadeæ.§

22. CLATHRARIA LYELLII (*Ligns.* 98, 99).—The most interesting plant belonging to this tribe of gymnogens, of which any vestiges have been found in the Wealden, is that first discovered by me in Sussex, and described under the name of *Clathraria Lyellii.*‖

* Zamiostrobus crassus; Medals of Creation, vol. i. p. 155.

† Fossils of Tilgate Forest, Pl. III. III*.

‡ Mon. Nord. Weald. Pl. III.

§ See Geology of the Isle of Wight, p. 212.

‖ Fossils of Tilgate Forest, Pl. I. II. and III. and Geology of the S. E. of England, Pl. I.

The fossil remains consist of portions of the stem, scored by the imprints left by the attachment of the petioles, also leaf-stalks, the internal axis, and obscure indications of the foliage and seeds.* The stem is composed of an axis, having the surface covered with reticulated fibres, and of a false bark, produced by the union of the consolidated bases of the petioles, the insertions of which are rhomboidal and transverse. The external surface is, in consequence, marked with lozenge-shaped elevated scars, separated from each other by lateral depressions, surrounded by a parallel band of a fibrous structure (see *Lign.* 97). This outer portion is sometimes consolidated into a compact cylinder of stone, which will separate from the central axis.† The latter is solid, and strongly marked externally with reticulated interrupted ridges. This surface has generally patches of vascular tissue adhering to it; and on some parts of the internal axis there are deep pits, indicating lacunæ which probably contained a resinous secretion, as in the Dragon-blood plant. In a water-worn specimen collected from the beach at Brook Point (*Lign.* 97), the internal structure, seen in thin transverse sections, resembles that of the Cycadaceæ.

LIGN. 97.—PORTION OF THE STEM OF CLATHRARIA LYELLII; FROM BROOK BAY. *(One-third natural size.)*

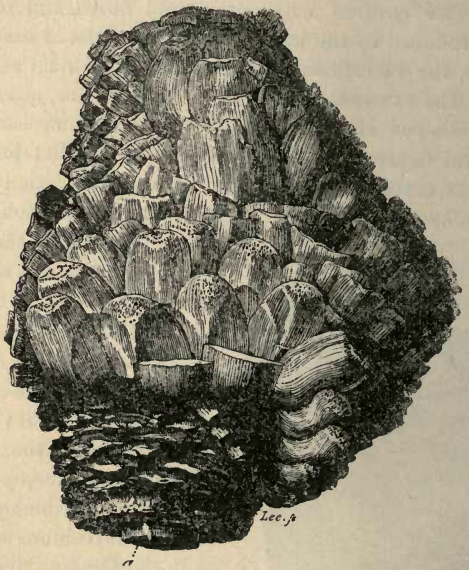
The most instructive example hitherto known was obtained from the upper greensand at Bonchurch in the Isle of Wight.‡ It consists of the summit of the stem garnished

* Medals of Creation, vol. i. p. 159.

† Fossils of Tilgate Forest, Plate II.

‡ Geology of the Isle of Wight, p. 215.

with persistent petioles, as shown in the annexed figure, *Lign.* 98. The original is fifteen inches in length; the upper part is entire, but the lower is broken, and exposes



LIGN. 98.—SUMMIT OF A STEM OF CLATHRARIA LYELLII;

From the Upper Greensand at Bonchurch, Isle of Wight; discovered by CAPTAIN IBBETSON.

This fossil is the summit of a stem furnished with petioles or leaf-stalks on the upper part; from the lower portion the petioles have been removed. The internal axis is seen at *a*. The original is fifteen inches in length, and eleven and a half in the widest transverse diameter. It is deposited in the collection of the Isle of Wight Fossils in the Polytechnic Institution, London.

the internal axis in its natural position (*a*), surrounded by the false bark, formed by the consolidation of the bases of the leaf-stalks. The surface of the lower portion of the

stem is bare, and scored with the lattice-like cicatrices, whence the name, *Clathraria*,* is derived: but the upper part, to the extent of 10½ inches, is covered by the petioles, some of which are abortive, being entire and rounded above; while others have their summits marked with vascular pits, disposed with great regularity, as shown in *Lign.* 99, *c*; these indicate the former attachment of leaves, that were shed naturally. Similar characters are observable in the petioles of the recent Zamiæ; † the presence of this characteristic plant of the Wealden so high up in the chalk-formation is in accordance with the occurrence of bones of the Iguanodon in the lower greensand of Kent, which we shall notice hereafter, and of Macropoma in the Purbeck and the Chalk.

In the strata of Tilgate Forest, the Clathrariæ are invariably associated with water-worn bones of reptiles, pebbles, gravel, and other drift; and are often imbedded in the conglomerate which is found in some parts of the Wealden. They appear to have floated down the river with the carcasses of the reptiles, and at length to have sunk to the bottom, and become imbedded in the mud of the delta and lagoons.

LIGN. 99.—A PETIOLE OF CLATHRARIA LYELLII; *from the stem of the specimen figured Lign.* 91.

a, The external surface; *b*, the internal surface; *c*, the vascular markings, left on the summit by the separation of the leaf.

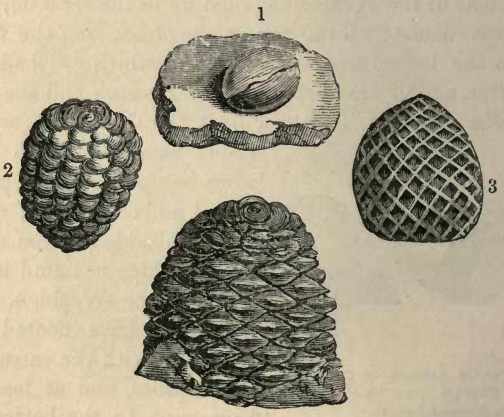
A cluster of petioles belonging to a large plant of the Clathraria has also been discovered in the lower greensand near Maidstone; in the same

* From Clathrum, a lattice.

† In a flourishing old plant of the *Encephalartus pungens* from South Africa, in the botanic gardens at Kew, all the lower part of the stem, beneath the coronet of foliage, is covered with persistent petioles; those which have borne leaves have vascular pits on the summit, but the abortive petioles are smooth and entire at the apex.

quarry of Kentish-rag in which were found, some years since, a considerable portion of the skeleton of an Iguanodon, associated with drifted coniferous wood and other vegetable remains. I have collected a few detached petiocles of Clathraria from the chalk and chalk-marl, near Lewes.

23. FRUITS OF CONIFERÆ.—The seed-vessels of several coniferous trees and plants have been discovered in the



LIGN. 100.—FOSSIL FRUITS FROM THE WEALDEN.

Fig. 1. Carpolites Mantelli, Brong. (Supposed seed-vessel of Clathraria Lyellii.) 2. Cone (Dammarites Fittoni, Unger) from the Isle of Purbeck. 3. Cone from Kent. 4. Cone from Pippingford, Sussex.*

Wealden, but under circumstances which render it impossible to determine whether they belong to the same species as the stems and leaves that occur with them. Several cones

* Figs. 2, 3, 4, are reduced one-half from Plate XXII. of Dr. Fitton's Memoir; Geolog. Trans. 2nd Ser. vol. iv.

of a species of Zamiostrobus were found with bones of the Iguanodon in Sandown Bay.*

A considerable number of small oval nuts or carpolithes (*Lign.* 100, *fig.* 1) have been obtained from the Tilgate grit; those are considered by M. Adolph Brongniart as probably belonging to the Clathraria.

The fossil fruits or cones figured in *Lign.* 100, *figs.* 2, 3, 4, are evidently referable to different kinds of coniferous trees. The specimen from Sussex, *fig.* 4, is remarkable for the double prominences on the scales. The cones from the lignite-beds at Brook Cliff, and which may possibly be the fruits of the pine-trees of the fossil forest in that locality, have been already noticed (p. 392): a cone resembling that of the Norfolk Island Pine has been found in the Purbeck dirt-bed at Portland (*Lign.* 100, *fig.* 2).

Four small carpolithes, and leaves of nine or ten (supposed) species of cycadeous plants, are described and figured by Dr. Dunker, from the Wealden of Germany.†

24. UNIVALVE SHELLS OF THE WEALDEN.—The durable remains of molluscous animals are most abundant; thick beds of limestone, spread over wide areas, and chiefly composed of but three or four species of bivalves and univalves, being a constant character of this group of deposits. The prevalent shells belong to a few common fresh-water forms, as *Paludina*, *Cyrena*, *Unio*, and *Anodon;* three or four other fluviatile, and an equal number of marine genera, the latter being very sparingly distributed, make up the conchology of the Wealden. Of the *Cyrena*, a fresh-water or estuarine bivalve allied to the *Cyclas*, which we have already noticed as abounding in certain tertiary strata, upwards of eight species have been determined; of the *Unio*, a well-known fluviatile mussel, ten; of the *Anodon*, another common fresh-

* One of these cones (under the name of *Zamites crassus*) is figured in Medals of Creation, vol. i. p. 156.

† Mon. Nord. Weald. Pl. II. IV. VII. pp. 16, 21.

water mussel, there are several undescribed forms: and of the river-snails, the *Paludinæ*, about four species. It is worthy of remark, that of the common lacustrine snail, the *Limnæa*, so abundant in the fresh-water tertiary beds of the Isle of Wight, but two Wealden species are known; and of the *Planorbis*, its constant associate in those deposits, and in our ponds and lakes, one or two only have been detected.* The *Physa*, another of the air-breathing fresh-water snail, is represented by one species (*Physa Bristovii*) in the Purbeck beds. The conchological fauna of the Wealden is, in fact, mainly fluviatile. In the Weald-clay there are a few oysters, and in some parts of the lower Purbeck beds layers of oysters and of corbulæ occur; and occasionally a stray marine shell is found in the fresh-water sediments; and in the upper part of the Wealden at Punfield Bay, Swanage, a bed of marine shells (discovered by Mr. Austen) is intercalated.

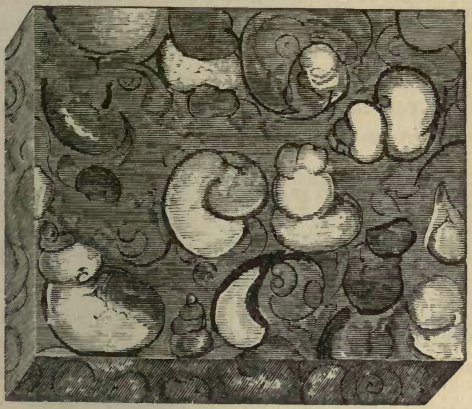
The several bands of marine shells bear evidence to the temporary influx of the sea into the old lagoon or high up the Wealden estuary, especially during the early or Purbeck period. But the last-mentioned marine intercalation (that seen at Punfield), corresponding to the more numerous and similar bands in the Wealden near Beauvais in France, indicates that oscillations of the land allowed the sea to come up over the estuarine deposits for limited periods before it gained permanent dominion over the sinking Wealden district, and covered it with the thick beds of greensands and chalk.

The most abundant shells of the fresh-water mollusca are the *Paludinæ*, of which the Sussex and Purbeck marbles are almost wholly made up: the former limestone differing from the latter, chiefly in the smallness of the shells of which it is composed.

The Sussex marble is a congeries chiefly of *Paludina flu-*

* Mon. Nord. Weald. Pl. X. figs. 1, 2. *Planorbis Inglesi*, and *Limnæa Hennei*, of Dr. Dunker.

viorum and *P. Sussexiensis*. In the coarse varieties of this stone, the shells are decomposed, and the insterstices left by their removal filled up with calcareous clay; but in the compact layers and blocks, the shells are transmuted into calcareous spar, and their cavities contain indurated marl and limestone, of various shades of grey, blue, yellow,



LIGN. 101.—POLISHED SLAB OF SUSSEX MARBLE.

(Chiefly composed of Paludinæ.)

&c., interspersed with pure white, mottled with black; the polished slabs (*Lign.* 101) display innumerable sections of the enclosed shells, and rival in interest and beauty many of the foreign marbles. The black and dark-brown spots and veins in this and other shelly marbles have originated from the transmutation of the soft bodies of the mollusca into a carbonaceous substance, termed *molluskite*.* Those shells which were empty at the period of their becoming imbedded had their cavities filled with mud, silt, or other detritus, which has subsequently hardened into clay, marl, limestone, &c.; but those which contained the gelatinous bodies of the

* See Medals of Creation, vol. i. p. 432.

snails are occupied by a mass consisting of carbon and a large proportion of phosphate of lime. In the polished sections of the marble, this carbonaceous animal matter often appears in black or dark-brown spots and veins; and the most beautiful slabs owe their variegated appearance to the contrast produced by the molluskite with the white calcareous spar. Upon examining thin slices of this marble under a slightly magnifying power, many of the shells, and the interstices between them, are seen to be filled up with the cases or carapaces of *Cypridæ* (*Lign.* 104).

The Purbeck marble differs from that above described in being composed of smaller shells of the same genus (*Paludina elongata*); it also contains abundance of Cypridæ; and in some layers, small bivalves (*Uniones*), replaced by white spar, give a variety to the markings exposed in the sections. The polished cluster-columns in the Temple Church at London, in Chichester and Canterbury Cathedrals, and many of the monuments in Westminster Abbey, are of this marble; in other words, they are constructed of conglomerated masses of petrified shells of snails, which lived and died in the rivers that flowed through a country inhabited by the Iguanodon and other extinct colossal reptiles, ages before a single layer of the chalk was deposited!

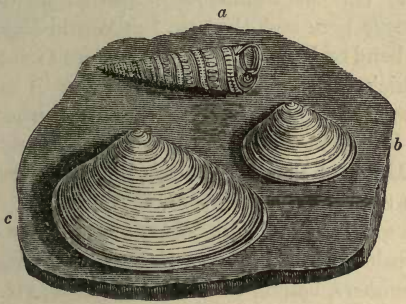
LIGN. 102.—POLISHED SLAB OF PURBECK MARBLE.
(Composed of a small species of Paludina.)

A few species of an elongated spiral fresh-water univalve (*Melanopsis*) are found in great perfection in some of the clays at Pounceford (*Lign.* 103, *a*), associated with the characteristic bivalves of the Wealden (*Lign.* 103, *b* and *c*). A Neritina occurs in the Purbeck beds, and a few specimens of

a small elegant species (*Neritina Fittoni*) have been found in the calciferous grit of Tilgate Forest and Hastings.

25. Bivalve shells.—We have already had occasion to observe that many kinds of the bluish-grey limestones of the Wealden are largely composed of small bivalves of the genera *Cyclas* and *Cyrena;* some layers form a compact marble that will bear a good polish. In the clay the shells are often beautifully preserved; as in these specimens from Pounceford (*Lign.* 103), in which remains of the epidermis and ligament are traceable.

The fresh-water mussels called *Uniones*, from their solid



Lign. 103.—Wealden shells, from Pounceford, Sussex.

a, Melanopsis tricarinata; *b*, Cyrena media; *c*, Cyrena membranacea.

pearly shells, occur in considerable abundance in some of the Wealden strata, but the species are, for the most part, of small size. But a remarkably fine and large species of Unio occurs in the cliff at Brook Point, imbedded with the fossil trees (see above, p. 390). I have named it *Unio Valdensis*, or Wealden river-mussel.* These shells are from four

* See Geology of the Isle of Wight, p. 221, for the description, and Pl. VI. *fig.* 1, for a figure of this fine fossil shell, which resembles some of the Uniones of the American rivers. Also Charlesworth's London Journal of Geology, Pl. XIV.; and Sowerby's Min. Conch. Pl. DCXLVI

to six inches long, and well preserved; the surface is of a tawny-red colour, the horny ligament with its transverse rugæ remains, and in some examples the shells are occupied by the body of the animal in the state of molluskite. The collocation of these large mussels with the drifted trees and bones of terrestrial reptiles, in strata so manifestly of fluviatile origin, completes the analogy between the rafts imbedded in the delta of the Wealden, and those brought down, and ingulfed in mud and sand, by the Ohio, Mississippi, and other large rivers.

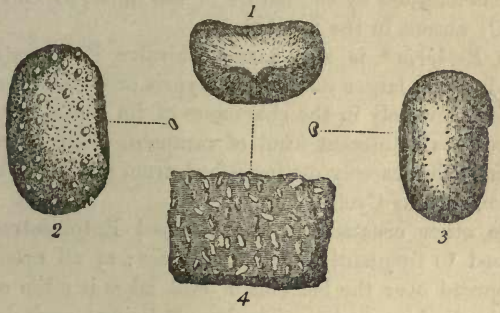
A few small estuarine mussel-shells (*Mytilus Lyellii*) occur in the clay at Pounceford, associated with Cyrenæ. Oysters occur here and there in the Weald-clay, and sometimes in a band or bed; and a small species (*Ostræa distorta*) forms a thick bed (known as the "Cinder") in the middle Purbeck series. The lower and middle Purbecks are the most rich in marine shells, for they afford Cardium, Pecten, Corbula, Modiola, Perna, Thracia, &c.; the first three occurring in considerable numbers.

26. CRUSTACEANS OF THE WEALDEN.*—The crustaceans of the Wealden and Purbeck, though occurring in inconceivable numbers, belong to but three kinds; viz. *Archæoniscus*, *Cypris*,† and *Estheria*. The first are referable to the isopodous order, of which our common *Oniscus*, or woodlouse, is an example; but these fossil *Isopoda*, like the modern

* Medals of Creation, vol. ii. p. 521, 527.

† These Entomostraca have not yet been examined and described by any crustaceologist. M. Bosquet has noticed the striking dissimilarity of their carapace-valves to those of the Cypris, and has proposed a new genus for them on that account (*Cypridea*). The *Cyprideis torosa*, described in Mr. R. Jones's Monograph of the Tertiary Entomostraca, 1856 (Palæont. Soc.), and obtained from the brackish ditches of Gravesend, appears to be, amongst the recent forms, the nearest to those of the Wealden. This Cyprideis is probably a sub-genus of Cythere; and, should it be found to represent the Wealden specimens, the latter will have to be

Asellus, were aquatic. They were discovered by Mr. Brodie, with remains of insects, in grey marly Purbeck limestone, near Dinton;* and they occur in numbers near Swanage and at Ridgway.



LIGN. 104.—FOSSIL CYPRIDES; FROM BROOK BAY.

Fig. 1. *Cypris spinigera*; the small figure shows the natural size.
2. *Cypris granulosa*.
3. *Cypris Valdensis*.
4. Clay, with carapaces of the species represented by fig. 1; of the natural size.

The Cyprides are very small fresh-water crustaceans of the family *Entomostraca*. Their body is enclosed in a horny bivalve shell or case, the two valves of which are united by a hinge, admitting the antennæ and feet to protrude and be at liberty, when the case or carapace is open.

There are also some marine Entomostraca (*Cytheres*) having much of the same characters as Cypris, but differing chiefly in the numbers and style of feet and antennæ, and

re-arranged as most probably belonging to the *Cytherinæ*, and of salt or brackish water habitat.

* Medals of Creation, vol. ii. p. 542; and History of Insects, p. 10.

more or less in the structure of the carapace-valves. Some of the smooth-valved species of Cythere have a very similar general appearance to some of the Cyprides and their close allies the Candonæ; and a minute examination even of the characters of the valves can scarcely supply the clear distinctions afforded by the nature of the limbs, which are necessarily absent in the fossil state.

The *Estheria* * is also a small bivalve Entomostracan; but it is much larger than either Cypris or Cythere, and not only differs widely in the characters of its limbs and body, but presents a different kind of carapace, which indeed can sometimes be scarcely distinguished from that of a bivalve mollusc, such as Cyclas, &c.

Like other crustaceans, the bivalved Entomostraca are supposed to frequently shed their cases; at all events the mud spread over the bottoms of still lakes is often covered with the dead carapaces. The largest living Cypris does not exceed one-eighth of an inch in length. In a fossil state their cases appear like whitish elliptical reniform scales on the surface of the recently separated laminæ of clay, shale, and limestone. Upon exposure to the air, the cases or valves decompose, and leave the surface of the shale or stone covered with the casts of the shells, which sometimes appear as minute polished tubercles; some layers of the indurated ironstone have a granulated surface on account of the presence of these remains.† In the Sussex and Purbeck marbles, as previously mentioned, the Cypridæ are most abundant; and there are several species in the Wealden beds of Germany.

As the recent species inhabit either still lakes or gently

* See Dr. Baird's papers on Estheria in the Proceedings of the Zoological Society.

† In the sandstone-quarries at Langton Green, near Tunbridge Wells, slabs of this kind occur, studded over with casts of Cypridæ and minute Uniones.

flowing streams, and not turbulent waters, it follows that sediments largely charged with these exuviæ, associated with fresh-water shells, afford strong presumptive evidence of a fluviatile or lacustrine * origin.

27. Insects of the Wealden.—The durable nature of the wing-cases (*elytra*), legs, antennæ, &c. of the Coleoptera and other insects rendered it probable that some vestiges of this class of articulated animals would be preserved in the muddy sediments of the Wealden; and in the vale of Wardour in Wilts, and in a few places in Buckinghamshire, the researches of the Rev. P. B. Brodie have been most successful, the acumen and perseverance of that gentleman having brought to light several hundred specimens of insects or parts of insects in the Purbeck beds. These consist chiefly of remains of *Coleopterous*, *Orthopteous*, and *Hemipterous* insects; with several kinds of *Diptera* and *Neuroptera*.

These fossil insects are mostly of very small size, especially the Diptera and Coleoptera; and if any inferences could be legitimately drawn from these limited observations, a low climatorial temperature of the country they inhabited would be indicated, as the magnitude of the insect tribes is in proportion to the heat of the climate. The insects discovered by Mr. Brodie, and described and figured by Mr. Westwood, comprise species of *Aphis*, cuckoo-spit insects (*Cercopidæ*), diamond-beetles (*Curculionidæ*), terrestrial crickets, cockroaches (*Blattæ*), and dragon-flies (*Libellulæ*); of the latter, which are inhabitants of the water in their first stage, and of the air in their last, there are relics belonging to species of gigantic size. As a general result, Mr. Westwood considers the entomological fauna of the Wealden to indicate a temperate climate.†

* Probably these are sediments of several lagoons or one great lagoon, in connexion with a river, and separated from the sea by, possibly, a narrow spit of sand or shingle, occasionally broken in by the waves.

† From Mr. Westwood's observations, in the elegant volume entitled,

Mr. J. O. Westwood's elaborate and interesting Memoir on the Fossil Insects of Purbeck, in the Quart. Journal of the Geological Society, vol. x. p. 378, is a valuable, and indeed necessary, sequel to Mr. P. B. Brodie's notice of the Purbeck Insects of Wilts (in his "History of Fossil Insects," &c.). In this account of the insect-fauna of the country whose rivers deposited the Wealden and Purbeck beds, Mr. Westwood points out the probably temperate climate of that old land. Or rather, taking into consideration the occasional presence of specimens of probably tropical insects among the crowd of individuals that, judging from the known habits of similar existing species, lived in a temperate climate, it is probable that the streams brought down innumerable insects, at certain periods (perhaps of heavy rains, for instance), from high lands of mild and cool climate, and mixed them with the remains of the very distinct forms of insect life peculiar to the hotter low lands of the delta and lagoons.*

Insect-remains have also been found in several beds of the Wealden proper. I have collected a few relics of beetles from the Wealden marls at Wateringbury near Maidstone; and Prof. E. Forbes discovered an insect's wing in the Hastings series in the Isle of Wight. A numerous series of insects, however, have been collected by Messrs. Binfield in the iron-stones and other strata of the Hastings cliffs.† These insects are in general aspect very similar to those from the Purbeck beds of Dorset and Buckinghamshire.

28. FISHES OF THE WEALDEN.—The fishes whose relics are distributed throughout the Wealden formation are, for the most part, of the shark-family, or of related genera, and of species allied to the large river-pikes of South America.

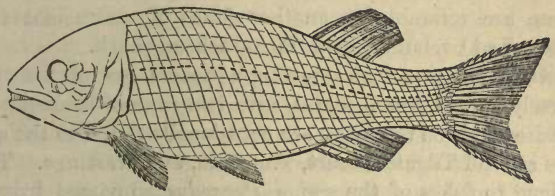
A History of the Fossil Insects of the Secondary Rocks of England, by the Rev. P. B. Brodie; one vol. 8vo, 10 plates. 1845.

* See the Rev. O. Fisher's Remarks, Cambr. Trans. vol. ix. p. 562; and D'Archiac, Hist. des Progrès de la Géologie, vol. v. p. 138.

† Quart. Journ. Geol. Soc., vol. x. p. 171.

A species of Macropoma, some small forms of the Sauroid fishes, and a few Pycnodonts complete the list. Detached scales, teeth, dorsal rays, and bones of these fishes are very abundant; and sometimes united portions of the skeleton and of the dermal covering are preserved.

Strong thick enamelled scales, bearing a high polish and having two processes of attachment, and small hemispherical teeth, called by the workmen *fishes' eyes*, are the most com-



LIGN. 105.—RESTORED OUTLINE OF THE LEPIDOTUS OF THE WEALDEN.

mon relics of this kind.* They belong to the *Lepidotus*, a genus related to the bony pike, which is their living representative inhabiting the lakes and rivers of America. In the grits and conglomerates of Tilgate Forest and of Hastings, these scales and teeth are in prodigious numbers. A few tolerably perfect specimens of the fishes from which these teeth and scales were derived have been obtained, and have enabled M. Agassiz to determine the form of the original (*Lign.* 105).† In the Purbeck strata a small species of Lepidotus is equally abundant.

* Medals of Creation, vol. ii. p. 637.

† A specimen in the British Museum (from my collection) has a considerable part of the cranium and body, with the dorsal and pectoral fins. Another (discovered by Robert Trotter, Esq., formerly of Borde Hill, Sussex) retains a mass of the scales in juxtaposition, more than a foot wide, near where the caudal fin commences; this fish must therefore have been ten or twelve feet long, and three feet wide.

Finely striated tricuspid teeth, and others of a transversely elongated shape, with a sharp elevated central cusp and several small lateral ones, are the next in frequency. These belong to fishes termed *Hybodonts*, and allied to the sharks, from which they did not materially differ in their habits and economy. They possess two dorsal spines or rays, and remains of these appendages are occasionally met with in the Tilgate grit and Hastings sandstone.*

I have found in the Tilgate grit a few small oblong teeth, with the surface of the crown covered by fine radiating striæ; these are referable to another genus of cestraciont fishes (*Acrodus* †) related to the Port-Jackson shark.

Small palatine bones, having a median row of flat transversely arched dental plates, with two rows of hemispherical obtuse teeth on the sides, are occasionally found in the quarries around Tilgate Forest, Horsham, and Hastings. These belong to fishes of the genus *Pycnodus*, so named from the thickness of their teeth, which are constructed for crushing hard substances. I have not observed any other determinable parts of these fishes.‡

Two very small fishes, belonging to the genus *Leptolepis* (one of the Sauroids), and two others equally minute, which are supposed to indicate new generic characters, were discovered by Mr. Brodie, in the strata containing insects, near Dinton, in the Vale of Wardour.§

29. REPTILES OF THE WEALDEN.—It is doubtless surprising to learn that the whole of the enormous bones and teeth before us are those of reptiles,‖ and that but few

* Medals of Creation, vol. ii. p. 578, 591. Fossils of Tilgate Forest, Pl. V. *fig.* 14; Pl. XV. *fig.* 2.

† Medals of Creation, vol. ii. p. 584. ‡ Ibid. p. 607.

§ History of Fossil Insects, Pl. I. *figs.* 1, 2, 3, 4; p. 15.

‖ This Lecture was illustrated by several hundred specimens of bones and teeth of reptiles from the Wealden; many of such magnitude, that the assemblage resembled an accumulation of the dissevered skeletons of gigantic elephants or mastodons.

vestiges of the mammalia occur in the Wealden deposits. Even these teeth, which so strikingly resemble the incisors of the Rhinoceros, and these bones of the feet and toes, which are so similar in shape and size to those of the Hippopotamus, belong to oviparous quadrupeds. Many of the specimens can be referred to certain extinct forms of saurians or lizards; but the affinities of others have not been exactly ascertained. The determination of these fossil bones is indeed no easy task; for, while in many deposits considerable portions of, or even the perfect skeletons, are often discovered, in the Wealden, with but few exceptions, every bone, tooth, and scale has been found apart from each other; and, as if to render the task still more perplexing, the relics of several different species and genera are scattered at random through the rocks. Nearly every specimen, too, bears evidence of having been transported from a distance. It would seem as if the carcasses of the animals had floated down the stream, and been rolled backwards and forwards by the tides, and the bones dissevered and broken, before they sank down and became imbedded in the mud of the delta. The weighty overlying masses of strata have subsequently compressed, distorted, and frequently crushed the largest and strongest of the bones. To collect these scattered fragments, and extricate them from the solid rock,—to reunite them into a whole, and assign to each skeleton of the respective animals the bones which once belonged to it, yet not to confound the different species together,—such is the labour which the comparative anatomist has to perform, who undertakes to investigate the nature of the Wealden Saurians. I reserve for the next Lecture some general observations on the economy and habits of reptiles, and will now refer only to the fossil relics from the Wealden.

30. TURTLES OF THE WEALDEN.—The bones and plates of chelonian reptiles * are very common in the Purbeck

* Medals, vol. ii. p. 726.

limestone, and in the grit, sandstone, and shale of Tilgate Forest.* They are referable to about nine fresh-water, or rather marsh, and two marine species; one of the former, named *Platemys Mantelli* by Prof. Owen,† was noticed by Cuvier ‡ as having some resemblance to a fresh-water turtle found in the Jura limestone at Soleure. It is a very flat species, and probably attained two feet in length.

Many ribs and other parts of the carapace of a *Trionyx* have been discovered in the shale of Pounceford and grit of Tilgate Forest; the external surface of the dorsal plates is shagreened all over, as is usual in these chelonians, which have no shelly covering, but only a thick, tough skin, or integument; the recent species inhabit the Nile and Euphrates.

Tretosternon Bakewelli.§ Among these remains of fresh-water turtles are costal and dorsal plates, and other bones of a chelonian reptile, which, in its essential characters, is closely allied to the *Trionyces*, but differs from all known recent species in having possessed a horny dermal integument formed of plates of tortoise-shell. This is indicated by the fossil ribs, which not only have a shagreen or punctated surface, like those of the recent species, but also imprints of the horny scutes or scales. Except in having a defensive coating of tortoise-shell, this turtle must have closely resembled the existing predaceous, soft, fresh-water chelonians; and doubtless, like those reptiles, inhabited the muddy beds of rivers and lakes, preying upon the eggs and young of the larger reptiles, and on the mussels and other fluviatile mollusca whose shells are commonly associated with its remains.

* See Prof. Owen's Monograph on the Purbeck and Wealden Chelonians (Palæont. Soc.), 1853.

† Monog. Wealden Chelonia, 1853, p. 11.

‡ Oss. Foss. tom. v. p. 232.

§ See Fossils of Tilgate Forest, p. 60, Pl. VI. *fig.* 1; Geology of the South-east of England, p. 225; and Medals, vol. ii. p. 737.

*Chelone Bellii.** A considerable portion of the carapace and plastron of a true marine turtle, belonging to a species three feet in length, was obtained from the sandstone of Tilgate Forest many years since, and some fragments are figured in my early works on the fossils of that district.

31. MARINE REPTILES OF THE WEALDEN.—By far the greater part of the bones obtained from the quarries of Tilgate Forest, Horsham, &c., and from the sea-cliffs of Hastings, Swanage, and Isle of Wight, belong to colossal terrestrial reptiles; but with these are associated the osseous remains of two or three genera which there is every reason to suppose were inhabitants of the sea into which the river flowed that deposited the strata of the Wealden.

Plesiosaurus. I have collected from various Sussex localities bones of the extremities as well as cervical and caudal vertebræ of one or more species of the extraordinary marine reptile called *Plesiosaurus*,† whose remains are found in such prodigious quantities in the Lias and Kimmeridge clay; thus, we have proof that this animal was at least an occasional visitant of the bays and estuaries of the Wealden river.

Cetiosaurus.‡ Some of the largest vertebræ and bones found in the Wealden strata belong to an aquatic reptile, probably of marine habits, and remains of which occur also in the oolites of Oxfordshire, &c. The vertebræ are distinguished by their nearly circular faces, and relatively short bodies; in the dorsal vertebræ the interior face is nearly flat, and the posterior concave; but in the caudal, both are concave, with a well-defined border, which gives the body a deeply excavated character. Some specimens are eight

* *Chelone Mantelli*, Fitzinger; *C. costata*, Owen. See Medals of Creation, vol. ii. p. 735.

† Fossils of Tilgate Forest, Pl. IX. figs. 4, 5.

‡ The name implies the affinity of these reptiles to the cetaceans. See Medals of Creation, vol. ii. p. 682.

inches in the transverse diameter of the articular face, and but four and a half in the antero-posterior length of the body of the vertebræ.*

The reptiles must have rivalled the living Whales in bulk, for some specimens indicate a length of forty or fifty feet; they are supposed to have had web-feet, and a broad vertical tail.† The bones found in the Wealden may have been transported from the sea by the tide, or the living animals may have occasionally been carried far up the river, as is sometimes the case with the modern cetaceans.

Pelorosaurus. Notices of vertebræ and limb-bones of a monster reptile, from Tilgate and Hastings, and named *Pelorosaurus*, may be found in the Philos. Transact. 1850, and in the Royal Institution Notices for 1852. In the opinion of some, however, these remains are referable to *Cetiosaurus.*

32. CROCODILIAN REPTILES OF THE WEALDEN.‡—The loricated or mailed saurian reptiles, as the Alligators, Crocodiles, and Gavials, of which numerous remains occur in the eocene strata, are well known as the largest existing forms of oviparous quadrupeds.

No relics of any living species have been observed in the secondary strata, but several allied genera appear to have flourished during these epochs. But the crocodilians of these ancient types differed materially in structure from the modern; and particularly in the vertebral column, which in one fossil genus only is composed of concavo-convex vertebræ, and these are in a reversed position; the ball or convexity of the bone being directed forwards, or anteriorly,

* I discovered a fine suite of four consecutive vertebræ in the sandstone of Tilgate Forest, and succeeded in extricating them entire from the rock. One of these vertebræ is figured in Philos. Trans. for 1841, Pl. IX. fig. 13.

† British Association Reports, 1841, p. 102.

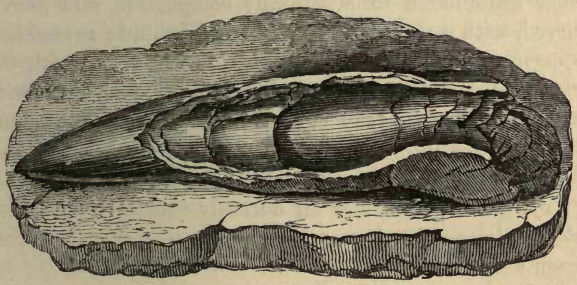
‡ Medals of Creation, p. 674.

instead of in the contrary direction, or posteriorly, as is the case in the living Crocodiles.

As a general character, it may be stated that the crocodilians with broad muzzles, as the Cayman and Alligator, do not occur fossil below the eocene deposits; all the reptilian remains of that family in the secondary formations belong to the division with elongated beaks or muzzles, like the Gavial (or Garial) of the Ganges.

*Streptospondylus.** The bones and jaws with teeth of the crocodilian reptiles to which this name (signifying *reversed spine*) has been applied were first discovered in the Jurassic clays of Honfleur and Havre; the vertebræ are united by a ball and socket joint; the convexity or ball being anterior, instead of posterior as in the living crocodiles. Several large vertebræ of these reptiles have been obtained from the sandstone and grit of Tilgate Forest, and from the variegated clays in Brook Bay, in the Isle of Wight.

33. Fossil Teeth of Crocodilian Reptiles. — The



Lign. 106.—Tooth of Crocodilian Reptile: from Tilgate Forest.

Natural size.

teeth of the Crocodile are very numerous; tney are of a conical form, and consist of a succession of cones, like a

* Medals of Creation, vol. ii. p. 680; and Petrif. p. 260.

series of thimbles, of various sizes, fitted into each other; they are striated externally, and have a prominent lateral ridge; as the outer tooth wears away, a new one is ready to supply its place; the teeth of the old Crocodile are therefore as fresh as those of the young animal but just escaped from the egg. The interior of the teeth is never completely filled up; hence, at whatever age a tooth may be removed, there is found, either in the socket or in the cavity of the tooth itself, a new germ, in a greater or less state of advancement, ready to occupy the place of the old one, when the latter shall be removed; and this succession is often repeated. In this fossil tooth (*Lign.* 106) from Tilgate Forest, the internal series of cones is exposed, in consequence of the removal of the outer case of the old tooth. Numerous fossil teeth, possessing this character, have been obtained from the Wealden; they are separable into two kinds.

The first is from an inch to two inches in length, of a slender acuminated form, laterally compressed, and gently recurved, with a thin edge in front and behind; resembling in appearance a small tooth of the Megalosaurus with the serrated edges worn off. Some biconcave vertebræ, with compressed wedge-shaped centres,* are supposed to belong to the same reptile, which has been named *Suchosaurus cultridens*.† The other form of tooth (*Goniopholis crassidens*) has a cylindrical base, and an obtusely conical crown with numerous longitudinal grooves and ridges, and a sharp line on each side.‡

34. SWANAGE FOSSIL CROCODILE. — The teeth last described are of comparatively frequent occurrence in the Wealden of the south-east of England, and are often associ-

* Fossils of Tilgate Forest, Pl. IX. *fig.* 11.

† British Association Reports for 1841, p. 68.

‡ Medals of Creation, vol. i. p. 667, Pl. VI. *fig.* 5. Fossils of Tilgate Forest, Pl. V. *figs.* 1, 2, 9. Petrif. and their Teachings, p. 171.

ated with dermal scutes or skin-bones, which are the osseous supports of the thick horny scales of the integument of mail with which the Gavials and other crocodilians are covered;* and certain extinct reptiles appear to have had these scutes even more largely developed. As the fossil teeth and dermal bones were commonly associated together, I was led to suppose that they might belong to the same species; an opinion which was confirmed some years since, by the discovery, in the Isle of Purbeck, of a considerable portion of the skeleton of a Crocodile, having similar teeth and dermal appendages.

In the summer of 1835, the workmen employed in a quarry in the immediate vicinity of Swanage had occasion to split asunder a large block of the Purbeck limestone, when, to their surprise, they perceived many bones and teeth on the surfaces they had just exposed. As this was no ordinary occurrence,—for, though scales of fishes, shells, &c. were frequently observed in the stone, bones had never before been noticed,—both slabs were carefully preserved by the proprietor of the quarry; and fortunately my friend, Robert Trotter, Esq., happening to visit Swanage a short time afterwards, heard of the discovery, and, with his usual liberality and ardour for the advancement of science, obtained the specimens, and presented them to me. I cleared away the stone, so far as the brittle state of the bones would permit without injury, and they are now two of the most interesting groups of crocodilian remains that have been discovered in this country.†

* See Medals of Creation, vol. ii. p. 657.

† Both the slabs of the Swanage specimen are now placed side by side in a case in the British Museum, in the same room with the remains of the Iguanodon and other fossil saurians. (Petrifactions, p. 169.) There can be no doubt that the entire lower jaw of this reptile might have been obtained, if the quarrymen had taken the precaution of examining the adjoining block of stone. In the same case are several teeth and dermal bones of this species from Tilgate Forest.

On one of the slabs, a considerable portion of the left side of the lower jaw, with two teeth in place, is preserved; and many detached teeth and dermal bones are distributed over the stone. There are numerous ribs and vertebræ, the latter are probably slightly biconcave; the chevron bones are of the same form as in the Gavial. The bones of the pelvic arch and several of those belonging to the extremities remain.

The dermal scutes are flat; their width, which is equal throughout, is about one-third of the length. They are of various sizes, from three to six inches long. The inner surface is smooth, and the external covered with irregular deep pits or hollows; some round, others angular. These differ from all known recent and fossil dermal bones, in having a lateral projection which fits into a corresponding depression on the under surface of the opposite angle of the adjoining scute.* Numerous hexagonal and pentagonal scutes, articulated together by marginal sutures, also entered into the composition of the osseous dermal cuirass; this reptile must, therefore, have possessed a flexible and impenetrable coat of mail, capable of affording protection against the attack of any assailant.†

Macrorhyncus Meyeri. The cranium of another reptile of the Gavial type has been found in the Wealden of Germany, and is figured in Dr. Dunker's beautiful work; it is characterized, as the name implies, by its extremely elongated snout.‡ Remains of Macrorhyncus are mentioned also by Prof. E. Forbes as having been found at Purbeck.

Pœcilopleuron. Vertebræ and other bones of a crocodilian reptile related to the *Goniopholis* are occasionally found in the Wealden deposits of Tilgate Forest and the Isle of

* Medals of Creation, vol. ii. p. 658.

† Teeth of the *Goniopholis* have been found in the Wealden of Germany; see Dunker's Mon. Nord. Weald. Pl. XX. *fig.* C.

‡ Mon. Nord. Weald. Pl. XX.

Wight, associated with the remains of that animal. The vertebræ are biconcave, and have a large medullary cavity in the middle of the centrum of the bone, which is often filled up with white calcareous spar. The body of the vertebra is contracted in the middle, the neural arch anchylosed without any trace of suture, and the spinous process is remarkable for its backward inclination.*

35. DINOSAURIANS.†—We now arrive at the consideration of three genera of extinct saurians or lizards, the Megalosaurus, Iguanodon, and Hylæosaurus, which so essentially differ in their osteological characters from all other known types as to constitute a distinct order, uniting the lacertian with the crocodilian oviparous quadrupeds. The remains of these animals principally occur in the Wealden deposits; but of the first, some of the most interesting relics have been obtained from Stonesfield, in the lower division of the Oolite; and of the second, a considerable portion of a skeleton has been found in the lower Greensand.‡ Other forms occur in the Upper Trias of Europe.

These genera comprehend the colossal crocodile-lizards §

* The remains of this reptile were first described by M. Deslongchamps (under the name of *Pœcilopleuron*) from specimens discovered in the Oolite near Caen, in Normandy. See British Association Report for 1841, p. 84. Fossils of Tilgate Forest, Pl. IX. fig. 8, represents a caudal vertebra.

† *Dinosaurians* signifying *fearfully great Lizards;* a term employed by Professor Owen to designate an order of extinct terrestrial reptiles, comprising the Iguanodon, Megalosaurus, and Hylæosaurus.

‡ See Petrifactions and their Teachings, p. 306.

§ See Medals of Creation, chap. xvii., for a concise view of the osteological characters of these reptiles; and Professor Owen's Report on Fossil Reptiles in the Transactions of the British Association of Science, for 1841, for a full consideration of the subject. Prof. Owen's Monographs on the Fossil Reptilia of Britain, now in course of publication by the Palæontographical Society, are indispensable to the student, containing, as they do, the results of matured knowledge and rigid examination, and

of the dry land of the secondary epoch. The long bones of the extremities of the first two genera above mentioned are of colossal proportions, and have large medullary cavities, with well-developed processes; their metacarpal, metatarsal, and digital bones, with the exception of the ungual phalanges (bones which support the nails or claws), more or less resemble those of the hippopotamus and other large pachydermal mammalia. A very remarkable peculiarity in the osteological characters of this extinct order of reptiles consists in the sacrum being made up of five vertebræ, anchylosed together into a solid mass or column, whereas in all other saurians it is formed of but two united vertebræ; and this is accompanied by another modification, for the neural arches of the vertebræ are shifted to the interspaces between the bodies of those bones; and thus great solidity is given to the pelvic arch. Both these arrangements have an evident relation to the great size of the hinder extremities of these reptiles, and the enormous carcass they had to support.

From the great magnitude of some of the bones, these fossils have excited the curiosity even of the common observer; and, although an exaggerated idea has been generally entertained of the size of the original animals, yet even when their assumed proportions are reduced to their natural dimensions by the rigorous formulæ of the comparative anatomist, they are sufficiently colossal to satisfy the most enthusiastic lover of the marvellous. Of this the reader may be easily convinced, if he will visit the British Museum, and, after examining the monster thigh-bones and leg-bones of the Iguanodon, repair to the zoological gallery and inspect the stuffed specimens of the existing species of Crocodiles and Alligators; then let him imagine the fossil bones to be clothed with appropriate muscles and integuments,

presenting detailed descriptions of the best specimens, illustrated by accurate and full-sized lithographs.

and consider the enormous trunk which limbs of such bulk must have been designed to support; and he will obtain some idea of the appalling magnitude of those

> "Mighty Pre-Adamites that walk'd the earth
> Of which ours is the wreck."—BYRON.

The student may also with advantage carefully examine the relative proportions of these and other great extinct reptiles in the admirable life-sized models constructed for the Crystal Palace gardens by Mr. Waterhouse Hawkins.

36. THE MEGALOSAURUS.*—The fissile oolitic shale of Stonesfield in Oxfordshire, of which I shall have occasion to treat more particularly in the next Lecture, has long been celebrated for its fossil remains; among which the teeth and bones of a very large animal have claimed particular attention.

LIGN. 107.—TOOTH OF A YOUNG MEGALOSAURUS: *from Tilgate Forest. (Nat. size.)*

The Rev. Dr. Buckland first pointed out the true character of these remains, and showed that they belonged to an extinct carnivorous reptile of enormous magnitude, which he distinguished by the name of *Megalosaurus*, or Gigantic Lizard.† Numerous teeth, vertebræ, and other bones of this reptile were among the earliest discoveries in the Wealden deposits of Tilgate Forest; and several examples are figured in my works on the geology of that interesting district.‡ The specimens from the Wealden consist of teeth, dorsal and caudal vertebræ, thigh-bones, and other bones of the extremities;§ they belong apparently to

* Medals of Creation, vol. ii. p. 687.

† Geol. Trans. vol. i. second series, p. 310.

‡ Fossils of Tilgate Forest, Pl. IX. p. 67.

§ Mr. S. H. Beckles, whose collection has been previously referred to as being rich in Wealden fossil, has obtained from the Wealden near

the same species (*M. Bucklandi*, von Meyer) as that of Stonesfield. The tooth of this reptile (*Lign.* 107) is disguishable by its sabre-like form, conical and laterally compressed crown, and finely serrated trenchant edges. From this structure of the tooth it may be inferred that the Megalosaurus was carnivorous: its length is estimated at nearly thirty feet.

Similarly shaped teeth characterize one of the diminutive reptiles found in the Purbeck beds, namely, the *Nuthetes destructor*.*

37. THE IGUANODON.†—Soon after my first discovery of remains of large vertebrated animals in the strata of Tilgate Forest, some teeth of a very remarkable character, in a block of stone on the road-side,‡ particularly engaged my attention, from their dissimilarity to any that had previously come under my notice. Additional examples were soon discovered; and at length I obtained a series of teeth in various conditions, from the pointed unused tooth of the young reptile (*Lign.* 108, *fig.* 2), to the obtuse, worn, flat crown of the adult (*Lign.* 110). From the resemblance in form of the perfect tooth to that of the Iguana,§ a terrestrial lizard

Battle, some remarkably fine relics of this great reptile. Three dorsal vertebræ form a magnificent specimen in this group, and is figured of the natural size in Owen's Monog. Weald. Reptilia, 1854, Pl. XIX.

* Quart. Journ. Geol. Soc. vol. x. p. 420; and above, p. 394.

† Medals of Creation, vol. ii. p. 691; Brit. Assoc. Reports for 1841, p. 120; Monographs of Cretaceous and Wealden Reptiles, Pal. Soc. 1851 and 1854; Petrifactions, chap. iii.

‡ Mrs. Mantell was the first to find specimens of these teeth; Geol. S. E. England, p. 268.

§ The Iguanas are land-lizards, which inhabit many parts of America and the West Indies, and are rarely met with north or south of the tropics. They are from three to five feet in length, and feed on insects and vegetables, climbing trees, and chipping off the tender shoots. They nestle in the hollows of rocks, and deposit their eggs, which are like those of turtles, in the sands or banks of rivers. The Iguana is furnished with a row of very small, closely-set, pointed teeth, with serrated edges,

of the West Indies, I proposed the name of *Iguanodon* (signifying an animal with teeth like the Iguana) for the extinct reptile to which they belonged.*

The numerous bones and teeth subsequently exhumed from the strata of Tilgate Forest, Horsham, Battle, Hastings, and other places in Sussex, and in the Isle of Wight,† and a considerable portion of the skeleton of an individual discovered in the lower Greensand of Kent, have supplied the data upon which our present knowledge of the characters of the original is based. Unfortunately the form and structure of the skull are still almost unknown; although two fragments of the upper jaw‡ and a nearly perfect half of the full-grown lower jaw,§ retaining some of the teeth, and parts of two lower jaws of young individuals, have come to light.

which have no distinct alveoli or sockets, but are attached at the base and by the outer surfaces of the fangs to the jaw; the alveolar process forms an external parapet, but there is no internal bony covering. The new teeth do not, as in the crocodile, spring up in the centre of the cavities of the old, and push through them, but arise from near the inner part of the base, and by pressure occasion the absorption of a portion of the fang of the old tooth, which they ultimately displace, by destroying the adhesion to the dental parapet. The teeth of the Iguana resemble the perfect fossil tooth (*Lign.* 108, *fig.* 2) in form, but not in structure or size; those of the recent lizard are not very much larger than the teeth of the common mouse. In the Iguana the crown of the tooth never presents a flat surface; it is broken or chipped off by use, but not ground smooth as in the herbivora. The reason is obvious; none of the existing reptiles are furnished with cheeks or movable coverings to their jaws, and therefore cannot perform mastication; their food or prey is seized by the teeth and tongue, and swallowed whole.

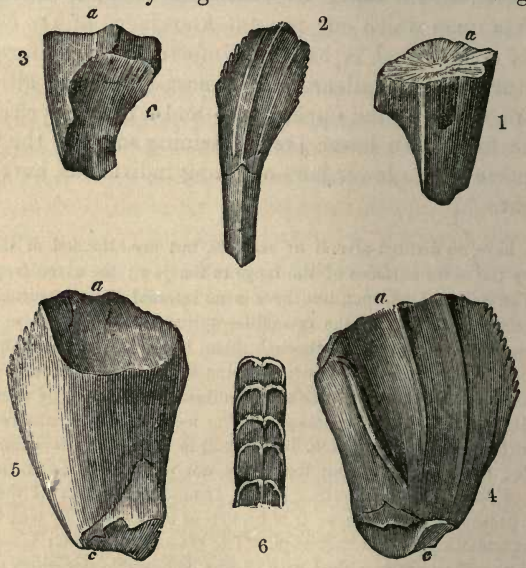
* See my memoir "On the teeth of the Iguanodon, a newly discovered fossil herbivorous reptile, from the strata of Tilgate Forest." Philos. Trans. for 1825.

† Geology of the Isle of Wight, pp. 98, 225.

‡ Philos. Trans. 1841, p. 131; and Palæont. Monog. 1853, p. 26.

§ Philos. Trans. 1848, p. 188; and Palæont. Monog. 1853, p. 23. See also Petrifactions, p. 243, &c.; and Medals of Creation, vol. ii. p. 693.

38. TEETH AND JAWS OF THE IGUANODON.*—The first specimen which arrested my attention was a portion of a large tooth which, from the flat surface of the crown, had evidently belonged to a herbivorous animal; for it possessed the prismatic form of a worn incisor of one of the large pachyderms. The enamel was thick in front and thin behind, by which arrangement a sharp cutting edge must have been maintained in every stage of use. There was no fang, but



LIGN. 108.—TEETH OF IGUANODON MANTELLI. FROM TILGATE FOREST.

Fig. 1. Outer aspect of an upper tooth (in a reversed position), worn flat, and with the fang absorbed: fig. 3. inner aspect of the same tooth. *a a*, Flat grinding surface, produced by mastication, when all the thickly enamelled portion of the crown is worn away. *c*, Cavity produced by the pressure of a new tooth.

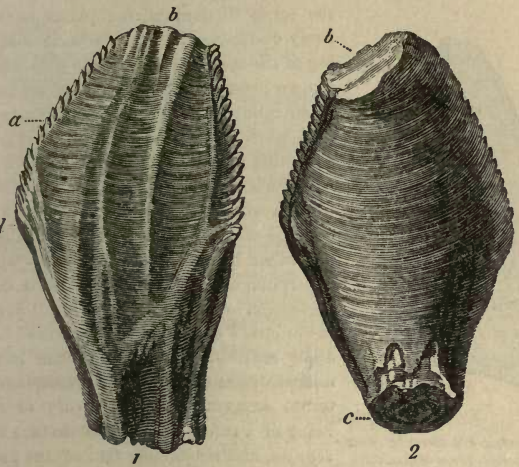
2. Lower tooth of a young animal, slightly worn; inner aspect.

4. Outer surface of a lower tooth of an adult; and fig. 5, inner surface of the same. *a a*, The hard cutting edge of the oblique surface worn by mastication. *c*, Indentation produced by the pressure of a successional tooth.

6. Edge-view of the serration on fig. 5, magnified.

* Medals of Creation, vol. ii. p. 693, &c.; Petrifactions, p. 235, &c.

the base was *indented*, not broken off; proving that the shank had been removed by absorption from the pressure of a new tooth, which had grown up and caused the old one to be thrown off.



LIGN. 109.—LOWER TOOTH OF IGUANODON MANTELLI. FROM THE TILGATE STONE. *(Natural size.)*

Fig. 1. Inner aspect, showing the longitudinal ridges and the denticulated margins of the crown of the tooth.

Fig. 2. Outer surface of the tooth.

a, The denticulated margin. *b*, The apex of the crown, worn by use; *b*, in fig. 2, showing the oblique smooth surface, produced by mastication. *c*, The fang, transversely fractured. *d*, Lower limit of the denticulated margin.

In the series of teeth before us (*Ligns.* 108, 109, 110) we may trace every gradation of this change; from the pointed, angular, perfect crown and fang (*Lign.* 108, *fig.* 2), and the partially worn specimen (*figs.* 4, 5), to the mere stump (*figs.* 1, 3), in which the summit is ground flat, and the shank entirely absorbed from the pressure of a successional tooth. The perfect teeth of the Iguanodon are distinguished by their prismatic form, the presence of from two to four or five ridges, which extend down the front, and the denticulated lateral margins of the crown (*Lign.* 108,

fig. 6). The latter appear as simple serrations in the figure, *Lign.* 109, *a*; but when viewed laterally (*Lign.* 108, *fig.* 6), are found to consist of denticulated plates.

The deciduous tooth of an adult Iguanodon, with the crown flat and the fang absorbed, is well exemplified in the specimen (*Lign.* 110) from the Isle of Wight, in which the crown is worn down almost to the neck; the series of denticulated plates having entirely disappeared. In this horizontal wearing of the teeth the Iguanodon differs from all known living or extinct lizards; for all other herbivorous reptiles chip off and swallow their food whole, the construction of their jaws not admitting of a grinding motion. It is therefore obvious not only that the Iguanodon fed on vegetables, but that it was to some extent capable of masticating its food like the horse and other herbivorous mammalia; while the absorption of the fang shows that a constant succession of teeth took place at all periods of the animal's existence, as is the case in many other reptiles. The tooth, when examined microscopically, exhibits a corresponding internal structure; the tooth-ivory or dentine being of a softer and coarser texture than in reptiles, and resembling that of the great vegetable feeders of the sloth tribe (above, p. 166.*) These dental instruments must therefore have been admirably adapted, in every stage of their growth, for the laceration and comminution of the tough vegetable substances which, there can be no doubt, constituted the chief food of this colossal quadruped.

LIGN. 110.—UPPER TOOTH OF IGUANODON MANTELLI; *from Brook Bay, Isle of Wight. (Nat. size.)* The crown flattened obliquely by wear; the fang partially absorbed.

It was not until Capt. L. Brickenden discovered (in 1848) a nearly perfect right half of the lower jaw of an adult Iguanodon, that the exact relations of the upper and lower teeth were clearly understood. This fine specimen exhibits also peculiar structural characters, and altogether throws important light on the structure and functions of the

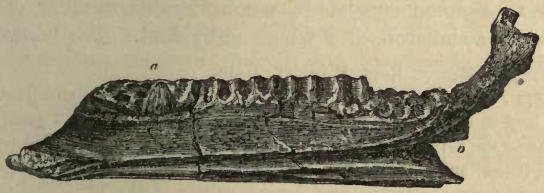
* Medals of Creation, vol. i. Pl. VI. *fig.* 4.

dental organs of the Iguanodon (*Ligns.* 111 and 112). A fragment of a smaller lower jaw, with implanted fangs, had been previously found, as well as a portion of an upper jaw;

LIGN. 111.—EXTERNAL VIEW OF THE LOWER JAW OF THE IGUANODON.

(One-seventh natural size.)

and a comprehensive and detailed description of these valuable and instructive specimens is given in Chapter III. of "Petrifactions and their Teachings."



LIGN. 112.—RIGHT SIDE OF THE LOWER JAW OF THE IGUANODON; FROM TILGATE FOREST, DISCOVERED BY CAPTAIN LAMBART BRICKENDEN, F.G.S.

(The inner aspect: one-seventh natural size.)

In Prof. Owen's masterly monograph on the Wealden Iguanodon (Palæont. Soc. 1854), the larger jaw-bone (Capt Brickenden's specimen) is re-described in full; also another young jaw-bone (Mr. Holmes's specimen), as well as a second portion of an upper jaw. The above-mentioned spe-

cimens are the only recognised portions of the bones of the head of the Iguanodon, excepting a large tympanic bone,* which is referred with some doubt to this great reptile.

The mode of implantation of the teeth (a character of importance in the classification of lizards) is pleurodontal: that is, the teeth are adpressed against the inside of the outer parapet-edge of the jaw; their setting, however, appears to have been strengthened by a low inner parapet and by sockets.

39. The Maidstone Iguanodon. *Plate* III.—In May, 1834, some workmen employed in Mr. W. H. Bensted's stone-quarry at Maidstone observed in a mass of rock which they had blasted several portions of what they supposed to be petrified wood; they preserved the largest piece for the inspection of the proprietor of the quarry, who perceiving that it was a portion of bone belonging to some gigantic animal, gave directions that every fragment should be collected, and succeeded in obtaining those pieces, which, when united and completely developed, formed the highly interesting fossil here delineated (*Pl.* III.).†

This specimen consists of a considerable number of the bones of a skeleton of a young individual. The bones are

* Owen's Monog. Rept. Wealden, p. 18.

† The rock was shattered to fragments by the explosion, and the bones were broken into a thousand pieces; but after much labour I succeeded in uniting the several blocks of stone, and ultimately cleared and repaired the bones, and restored the specimen to its present state. It is placed in a large frame in the palæontological gallery of the British Museum. The circular hole seen near the centre of the fossil was made to introduce the charge of powder for blasting the rock. The specimen now measures 6 feet 4 inches in length; originally it was about eight feet long (see Pl. III.); but the terminal group of four vertebræ, with the accompanying fragments, were removed (apparently to make the specimen fit the hexagonal glass-case, in which it was formerly fixed) from their right position, and let into the block at the corner, near the thighbones and ilium, where they are now seen. See also "Petrifactions," p. 303, &c.; and Prof. Owen's "Monograph of the Cretaceous Reptiles," 1851 (Palæont. Soc.).

imbedded in the stone in a very confused manner; few of them lying in their natural order of juxtaposition, and all being more or less flattened and distorted. The following are the most important, and the best preserved; but there are numerous fragments, too imperfect to admit of determination:

Two *thigh-bones*, each 33 inches long. *Plate* III. *figs.* 1, 2.
One *leg-bone* (*tibia*), 31 inches long. *Fig.* 3.
Metatarsal and *phalangeal* bones of the hind feet. *Figs.* 4, 4, 4.
Two claw-bones (*ungual bones*), which were originally covered by horny claws. *Fig.* 5 (the upper fig. 5).
Bones of the fore leg (*Ulna* and *Radius*) [Owen]. *Fig.* 6.
A *humerus*, or bone of the arm or front leg. *Fig.* 7.
Several *dorsal* and *caudal vertebræ* (bones of the spine and tail). *Figs.* 8, 8; and the lower fig. 5.
Fragments of several ribs. *Figs.* 9, 9.
Two *clavicles*, or collar-bones, resembling the bone figured *Plate* IV. *figs.* 1, 2, Geology of the South-East of England. These bones are of a very singular form, and differ essentially from any known clavicle. *Figs.* 10, 10.
Two large flat hatchet-shaped bones, which belong to the pelvis (*iliac bones*). *Fig.* 11, and the bone under figs. 9 and 8.
Two *scapulæ* (blade-bones); one of these lies broken across the femur, fig. 2; the other is partly seen beneath.
A *chevron-bone*, or inferior spinous process (hæmal arch) of a vertebra of the tail. *Fig.* 12.
A portion of a tooth, and the impression of another.—The preservation of these relics was most fortunate, as the identity of the animal with the *Iguanodon* of Tilgate Forest was thereby completely established.

The geological position of this specimen forms an exception to what has been previously remarked of the remains of the Iguanodon from the Wealden; for, while in the latter the bones are associated with terrestrial and fluviatile exuviæ, the Maidstone fossil was imbedded in a marine deposit.* This discrepancy, however, does not affect the

* The stone in which the bones are imbedded is of that hard variety

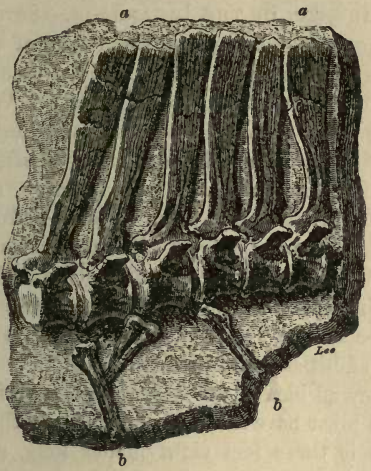
arguments previously advanced as to the fluviatile origin of the strata of the Wealden; it merely shows that part of the delta had subsided, and was covered by the chalk-ocean, whilst the country of the Iguanodon was still in existence; and that the body of one of these reptiles was drifted far out to sea, and sunk down in the depths of the ocean; just as at the present day bones of land-quadrupeds may not only be ingulfed in the deltas of rivers, but also in marine deposits far from land.

40. VERTEBRÆ OF THE IGUANODON.—The peculiarities in the vertebral column of the Iguanodon are pointed out in the Medals of Creation,* and anatomical details would here be irrelevant: a few particulars must, however, be noticed. The transverse processes of the dorsal and lumbar vertebræ are very long and straight, indicating a considerable expanse of the abdominal cavity, suitable for the capacious viscera of a herbivorous quadruped. In the caudal vertebræ, both the spinous processes (*Lign.* 113, *a*, *a*) and

of the grey, arenaceous limestone, called *Kentish rag*, which is much employed for building, and for repairing the roads. It belongs to the Lower Greensand, and abounds in the marine shells which are characteristic of that division of the chalk-formation. In the quarry in which the remains of the Iguanodon were found, there have been discovered wood perforated by boring shells, impressions of leaves and stems of trees, with *trigoniæ*, *ammonites*, *nautili*, &c., conical striated teeth of the marine reptile called *Polyptychodon* (above, 367), some of which are two inches in diameter at the base, and a few remains of fish. Molluskite abounds in these strata. It may be here remarked that, although Mr. Austen, in his remarks on the Wealden, and Prof. Owen, in his descriptions of the Iguanodon, term the Lower Greensand of England "Neocomian," this is not correct; for, as M. Renevier has lately shown (Bulletin de la Société Vaudoise, vol. v. p. 51), the sandy series of our Lower Greensand is paleontologically the "Aptian" of D'Orbigny; and the Atherfield beds, or the lowest portion of the Lower Greensand, represent the "Rhodanian series" which lies upon the Upper Neocomian in the South of France.

* Vol. ii. p. 653.

the chevron-bones (*b*, *b*) are of great length; the latter have their bases so blended as to form but one face for articulation with the truncated inferior angles of the body of the



LIGN. 113.—SIX CAUDAL VERTEBRÆ OF AN IGUANODON; FROM TILGATE FOREST.

(One-sixteenth natural size.)

a, *a*, *Spinous processes* (neural spines), fifteen inches high. *b*, *b*, *Chevron-bones* (hæmal spines), imbedded in the stone near their original articulation between two of the vertebræ.

vertebræ, leaving a vertical and elongated channel, for the passage of the large blood-vessels of the tail. The proportions of these elements of the caudal vertebræ indicate a great vertical development of the tail. In the fine specimen before us (*Lign.* 113) of six united caudal vertebræ, imbedded in a block of Tilgate grit, with both the upper and under spinous processes displayed, these characters are strikingly obvious. The width, or rather height, of that portion of the tail to which these bones belonged must have been at least twenty-seven inches. This compressed form

of the tail-bones, and the relative shortness of the humerus, are referred to by Prof. Owen as evidences of the probable aquatic habits (to some extent, at least) of this mighty reptile.

41. FEMUR, &c., OF THE IGUANODON.—Several specimens of the femur or thigh-bone, of the bones of the hind legs, and of the metatarsal, phalangeal, and ungual bones,* have been obtained from various localities of the Wealden. The first fragment of a thigh-bone that came under my notice was a portion of the middle part of the shaft, which is of a quadrangular form; and this was so large, shapeless, and unintelligible, that many years elapsed before I obtained any clue to its real nature.† The toe-bones presented so little correspondence with those of reptiles, and such a similitude to the metatarsals of the large pachyderms, as for example those of the Hippopotamus, that it was long before their true affinities could be determined.

To convey an idea of the enormous size which some adult individuals must have attained, I may state that one perfect thigh-bone is three feet eight inches long, and thirty-five inches in circumference at the condyles, and that some fragments indicate a greater magnitude; the average length being about four feet six inches.‡

The femur of the Iguanodon is remarkable from the combination of mammalian characters which it presents, in its well-marked head and neck, trochanters, condyles, and medullary cavity. The head (*Lign.*

* Some specimens of a conical bone, about four inches long, have been found in the Wealden, and regarded as being probably the osseous supports of a horny protuberance belonging to the snout of the Iguanodon, and similar to the conical warts and processes which some of the Iguanas possess. Prof. Owen, however, refers these peculiar and almost symmetrical bones to the feet, regarding them as the ungual phalanges or claw-bones of the outer toes of, perhaps, the hind-feet.

† This fragment is figured in Foss. Til. Forest, Pl. XVIII.

‡ Petrifactions, p. 300.

114, *f*) is hemispherical and projects inwards; and a laterally flattened process or trochanter (*a*) forms an external buttress or boundary of the neck of the bone, from which it is separated by a deep, narrow, vertical fissure. The shaft of the bone is subquadrangular; a slightly elevated ridge, produced by the union of two broad, flat, longitudinal surfaces, indicating the attachment of powerful muscles, extends down the middle of the anterior face; and, diverging towards the inner condyle, gradually disappears. The shaft terminates below in two large, rounded, and laterally-compressed condyles (*c*, *d*), which are separated in front and behind by a deep groove (*e*). Near the middle of the shaft, the mesial or inner edge forms a compressed ridge, which expands into an angular projection, or trochanter (*b*). Thus the upper part of the femur may be known by the presence of the upper trochanter (*a*); and if that process be broken away, the fractured surface indicating its position will be detected. If a fragment of the middle part of the shaft only be found, the flattened angular spaces, and the submedian trochanter (*b*), or the mark of its attachment, will identify it. The lower extremity of the femur may be distinguished by the deep groove (*e*) between the condyles, both in front and behind. The medullary cavity is very large.

LIGN. 114.—LEFT FEMUR OF AN IGUANODON. *From Brook Bay.*

(The original 40 inches in length.)

a, Upper trochanter.
b, Middle trochanter.
c, Inner, *d*, outer, condyle.
e, Groove between the condyles.

42. PROBABLE FORM AND SIZE OF THE IGUANODON.—From numerous detached bones that have been collected from various localities of the Wealden, and with the aid of the few specimens in which several are collocated in the same block of stone, the size and proportions of

the body and limbs of the Iguanodon have been determined; yet but a vague idea of the form and appearance of the original animal can be derived from the relics hitherto discovered. For the great discrepancy between the known parts of the skeleton of this creature and the corresponding bones in the largest existing saurians militates against the perfect restoration of the form of this colossal reptile, until the skull, jaws, feet, &c. are better known.*

In the present state of our knowledge we may, however, safely infer, that the body of the Iguanodon was equal in magnitude to that of the elephant, and as massive in its proportions; for, being a vegetable feeder, a large development of the abdominal region may be inferred. Its limbs must have been of a proportionate size to sustain so enormous a bulk; one of the thigh-bones (in the British Museum), if covered with muscles and integuments of suitable proportions, would form a limb seven feet in circumference. The hinder extremities, in all probability, presented the unwieldy contour of those of the hippopotamus or rhinoceros, and were supported by very strong short feet, the toes of which were armed with claws like those of certain turtles. The fore-legs appear to have been less bulky, and were furnished with hooked claws resembling the ungual phalanges of the Iguana. The teeth demonstrate the nature of the food required for the support of this herbivorous reptile, and the power of mastication it enjoyed; and the ferns, cycadeous plants, and coniferous trees with which its remains are associated indicate the flora adapted for its sustenance. But

* Mr. W. Hawkins's highly artistic and picturesque restorations of the Iguanodon in the Crystal Palace gardens well express in material form the amount of anatomical information as yet accumulated by Mantell, Owen, and others from the study of the relics of the skeleton of the Wealden monster. It is to be hoped that better structural evidences of the skull, feet, skin, &c. than are at present possessed will be procured before long by the unwearied researches of the Wealden collectors.

the physiognomy of this creature, from the peculiar modification of the skull and jaws required for the attachment and support of the powerful muscles necessary for the trituration of tough vegetable substances, must have differed considerably from that of all known saurians.

The length of the Iguanodon has been variously estimated; the difference in the computation depending chiefly on the extent assigned to the tail, which in the Iguana and many other lizards is much longer than the body. If the tail of the fossil reptile was slender, and of the same relative proportions as in the Iguana, the largest individual would be fifty or sixty feet long; but it is more probable, from the shortness of the bodies of the caudal vertebræ, that the tail was comparatively short, and flattened on the sides, as in some living reptiles,—for example, the *Doryphorus;* in that case, the length of a full-grown Iguanodon would but little exceed thirty feet.

From what has been advanced we may conclude, that the Iguanodon was a gigantic, but inoffensive, herbivorous reptile, amphibious in its habits, and living on the ferns, zamiæ, and coniferæ that constituted the flora of the country of the Wealden, of which it appears to have been the principal inhabitant.

43. THE HYLÆOSAURUS, or *Wealden Lizard;* Plate IV. —This is another reptile of the Wealden, possessing the same remarkable construction of the sacrum as the Iguanodon, and which I have distinguished by a name indicative of the geological formation in which its remains occur.* The first and most important specimen of the Hylæosaurus † was discovered in the summer of 1832, under the following circumstances.

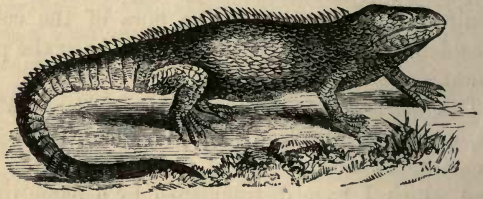
Upon visiting a quarry in Tilgate Forest, which had yielded many organic remains, I perceived in some frag-

* From ὑλη, a wood (Weald); and σαυρος, a lizard.

† Medals of Creation, vol. ii. p. 689; Petrifactions, p. 314.

ments of a large mass of grit which had recently been broken up and thrown on the road-side traces of numerous pieces of bones. I therefore collected all the recognisable portions of the block, and had them conveyed to my residence. Having cemented the fragments together, and chiselled off the stone in which the bones were imbedded, so far as their brittle state would admit, I succeeded, after much labour, in developing a considerable portion of the skeleton of a reptile, in which are blended the osteological characters of the crocodiles with those of the lizards.

The vertebræ of the neck (*Pl.* IV. 2), several of the back (3, 3), many ribs (4, 4), the two coracoid bones (7, 7), and scapulæ (8, 8), remain not far removed from their natural order of juxtaposition. There are also several dermal or skin-bones, which supported the thick scales or scutes; of these the most extraordinary are certain large angular bones (5, 5, 6, 6), which lie in the direction of the vertebral column, and appear to have extended along the back, like the horny serrated fringe in the Iguana. Many other existing lizards have



LIGN. 115.—CYCLURA CARINATA

(A recent Lizard, allied to the Iguana. Dr. Harlan.) *

appendages of this kind, which in some genera are largely developed; as for example in the *Cyclura* (*Lign.* 115).

* Medical and Physical Researches, by R. Harlan, M.D., 8vo, Philadelphia, 1835, p. 203.

There are several detached bones dispersed in the block of stone; and numerous vegetable remains, and carpolites, or seed-vessels, of the Clathraria (above, p. 412), were detected in reducing the size of the mass.*

Dermal bones and spines.† The structure of the dermal bones is very peculiar, and closely resembles that of the ligamentous fibres of the *corium*, or skin, and seems to have resulted from an ossified condition of the dermal integument.‡ Upon inspecting the surface exposed by a transverse fracture of the oval scutes, minute osseous spiculæ, decussating each other at right angles, are visible to the naked eye; and, under the microscope, the same arrangement is found to prevail in the minutest bony fibres; the medullary canals have fine lines radiating from them.

The same internal structure characterizes the large triangular spinous bones (*Pl.* IV. 5, 6); and this fact tends to confirm the opinion that they also are ossified dermal processes, which formed a longitudinal crest along the back of the animal.

The Hylæosaurus was probably a terrestrial herbivorous reptile, between twenty and thirty feet in length. The modification of form in the bones composing the sternal arch—in which a coracoid of the lacertian type is united with a scapula like that of the crocodiles—together with other osteological peculiarities, and the largely developed dermal processes, all combine to point out the original as a most extraordinary type of reptilian organization.§

* For further particulars see my Geology of the South-East of England, p. 316. Pl. V. of that work is an excellent lithograph of this specimen, by Mr. Pollard, of Brighton.

† Medals of Creation, vol. ii. p. 660.

‡ See my Memoir on the Fossil Reptiles discovered in Tilgate Forest, Philos. Trans. for 1841.

§ The Hylæosaur, with its spiny back and malicious aspect, occupies a prominent place with the Iguanodons and Megalosaur in the Crystal Palace Gardens.

LIGN. 116.
TOOTH OF THE HYLÆOSAURUS?
From Tilgate Forest; natural size.

As the jaws have not yet been found, the characters of the dental organs are unknown; but I have long considered the teeth before us (*Lign.* 116) as probably referable to the Hylæosaurus. They are generally from one inch to one and a half inch long, with a cylindrical shank, which enlarges into an obtuse, lanceolate crown, convex in front, and depressed behind; the margins of the crown are invariably worn, as if by use: the internal structure consists of firm dentine, with extremely minute tubes radiating from the centre to the periphery of the tooth, which has a thick coat of enamel.*

44. PTERODACTYLES AND BIRDS OF THE WEALDEN.—In the Wealden, numerous fragments of bones which from their tenuity must have belonged to animals capable of flight have been obtained from various localities. Several are figured in my Fossils of Tilgate Forest. The imperfect state of the specimens renders it extremely difficult to determine whether any of these bones belong to a higher order of animals than reptiles,—whether, in fact, some of them are not referable to birds. One fragment of bone in particular, at first regarded as part of a tarso-metatarsal bone of a bird, has been recognised to be a broken *humerus* or arm-bone of a Pterodactyle;† and the microscopical characters of its internal structure also show it to be reptilian. Mr. Bowerbank‡ has

* Medals of Creation, vol. ii. p. 690. Just as the little *Nuthetes* of the Purbeck imitates the great Megalosaur in the form of its teeth, so does the minute *Saurillus* of the same deposits present miniature teeth of the pattern of those here referred to the Hylæosaurus.

† Geol. Trans. 2 Ser. vol. v. p. 175; Quart. Geol. Journal, 1846, p 96, and p. 104; Petrifactions, p. 190.

‡ Quart. Geol. Journal, vol. iv. p. 2.

found a recognisable difference in the form and proportion of the minute cells of bones, which he believes is constant, and by which the smallest fragment of bone may be referred to its proper class. In *Birds* under a power of 500 linear, by transmitting light, the cells are found to have a breadth in proportion to their length of from one to four or five; while in *Reptiles*, the length exceeds the breadth ten or twelve times. For example:—

In the Albatross, the width of the cell is $\frac{1}{4}$ the length.
— Crocodile, — — — $\frac{1}{12}$ —

Applying this test to the bones from the Wealden, Mr. Bowerbank finds that some specimens exhibit under the microscope cells of the reptilian type; while some other of the specimens (especially that figured in Geol. Trans. Ser. 2, vol. v. Pl. XIII. *fig.* 6) have short elliptical cells, as in true birds; they are therefore presumed to belong to that class.

45. THE COUNTRY OF THE IGUANODON.—By this survey of the strata and organic remains of the Wealden, we have acquired data from which, by the principles of induction already explained (p. 377), we may obtain secure conclusions as to the nature of the country whence those spoils were derived, of the animals by which it was inhabited, and of the vegetables that grew upon its surface. Whether that country was insular or continental cannot be determined; but that it was diversified by hills and valleys, and irrigated by streams and rivers, and enjoyed a climate of a higher temperature than any part of modern Europe, is most evident. Arborescent ferns, coniferous trees, and cycadeous plants constituted its groves and forests, with delicate ferns amongst the vegetable clothing of its soil; and in its fens and marshes the equiseta and plants of a like nature prevailed. Its principal herbivorous quadruped was the enormous lizard, the Iguanodon; its carnivora, the Megalosaurus and other predaceous reptiles; its insectivora, the little

warm-blooded Spalacotheres, and their companions, the reptilian Macellodus and Saurillus; crocodiles and turtles frequented its rivers, and deposited their eggs on the banks and shoals; its waters teemed with fishes, molluscs, and minute crustaceans; and its air with insects. Some inferences relating to the prevailing atmospheric condition of the country may also be drawn from the undulated surfaces of the sandstones, and from the fossil trees. In the former we have proof, that when the land of reptiles existed the water was rippled by the breezes, which then, as now, varied in intensity and direction in a brief space; by the latter, that in certain situations the wind blew from a particular quarter for a great part of the year, and that the mean annual temperature was as variable as in modern times.

From what has been advanced, it must not, however, be supposed that the country of the Iguanodon occupied the site of the south-east of England; and that the animals and terrestrial plants of the Wealden lived and died near the spot where their relics are entombed. For, with the exception of the shells and crustaceans, which probably inhabited the waters of the delta, nearly all the fossil remains bear marks of having been transported from a distance. But, though three-fourths of the bones we discover have been broken and rolled, — the teeth detached from their sockets,—the vertebræ and bones of the extremities, with but very few exceptions, disjointed and scattered here and there,—the stems and branches of the trees torn to pieces and deprived of their foliage,—there is but little intermixture of sea-shells, or of beach or shingle; these remains have been subjected to abrasion from river-currents and the tides of the estuary, but not to attrition from the waves of the ocean. The gigantic limbs of the large reptiles could not have been dissevered from their sockets without great violence, except by the decomposition of their tendons from long maceration in water; and, if the latter had been the

sole cause, we should not find the bones broken and separated, but lying more or less in juxtaposition, like the skeletons of the Plesiosaurs and other reptiles in the Lias. The condition in which these fossils occur proves that they were floated down the river with the rafts of trees and other spoils of the land, until, arrested in their progress, they sank down and became imbedded. The phenomena here contemplated cannot, I conceive, be satisfactorily explained upon any other grounds; and the source of the mighty stream which flowed through the country of the Iguanodon must, therefore, like that of the Mississippi, have been hundreds, perhaps thousands, of miles distant from the delta accumulated in the course of ages at its mouth.

Such was the country of the Iguanodon,—a country which language can but feebly portray, but which the magic pencil of Martin, by the aid of geological research, has rescued from the oblivion of the past, and placed before us in all the hues of nature, with its appalling dragon-forms, its forests of palms and tree-ferns, and the luxuriant vegetation of a tropical clime.*

46. SEQUENCE OF GEOLOGICAL CHANGES.— Let us now review the sequence of those stupendous changes, of which our examination of the geological phenomena of the south-east of England has afforded such incontrovertible evidence. From the facts brought before us, we learn that at a period incalculably remote there existed in the northern hemisphere an extensive island or continent, possessing a climate of such a temperature that its surface was clothed with coniferous trees, arborescent ferns, and plants allied to the Cycas and Zamia; and that the ocean which washed its shores was inhabited by turtles and marine lizards of extinct genera. This country suffered a partial subsidence, which

* See the Frontispiece; an engraving on steel, from an original painting for the author, by John Martin, Esq., K. L.

was effected so tranquilly that many of the trees retained their erect position, and the cycadeous plants and a considerable layer of the vegetable mould in which they grew remained undisturbed. In this state an inundation of fresh-water covered the country and its forests, and deposited upon the soil and around the trees a calcareous mud, which was gradually consolidated into limestone; and water holding flint in solution percolated the mass, and silicified the submerged trees and plants.

A further subsidence took place, floods of fresh water overwhelmed the petrified forest, and heaped upon it accumulations of detritus, which the streams and rivers had transported from the land. The country traversed by the rivers, like that of the submerged forest, enjoyed a warm climate, and was clothed with arborescent ferns and cycadeæ; it was tenanted by small mammalia, gigantic herbivorous and carnivorous reptiles, and innumerable insects, and its waters abounded in turtles and various kinds of fishes, crustaceans and molluscs. The bones of the mammals and reptiles, the teeth and scales of the fishes, the bodies and wings of the insects, and the stems, leaves, and seed-vessels of the trees and plants, were brought down by the streams, and imbedded in the mud of the delta, beneath which the petrified forest had long been buried.

This state continued for an indefinite period;—another change took place,—the Country of Reptiles with its inhabitants was swept away, and the delta, and the fossil trees, with the marine strata on which they grew, subsided to a great depth, and formed part of the bottom of a profound ocean; the waters of which teemed with numberless zoophytes, shells, and fishes, of species long since extinct. The influx of thermal streams charged with silex, or long-continued chemical agencies, gave rise to layers and veins of nodular and tabular flint, and occasioned the silicification of

the organic remains subjected to their influence, amidst the calcareous debris of shells, foraminifera, and moss-corals now presented to us as Chalk.

This epoch, which was of long duration, was succeeded by elevatory movements, by which the bottom of the deep was broken up, and large areas were slowly upheaved; and as the elevation continued, the deposits which had accumulated in the depths of the ocean approached the surface, and were exposed to the action of the waves. These masses of cretaceous strata now began to suffer destruction, and parts of the delta of the country of the Iguanodon gradually emerged above the waters, until even the petrified forest of Portland rose in the midst of the sea, and became dry land. At length, some portions of the elevated strata attained an altitude of several hundred feet, and a group of islands was formed; but in the basins or depressions beneath the waters, sediments derived from the disintegration of the sea-cliffs were deposited. Large herbivorous mammalia now inhabited such portions of the former ocean-bed as were covered with vegetation sufficient for their support; and, as these animals died, their bones became enveloped in the accumulations of mud and gravel, which were forming in the bays and estuaries.

This era also passed away;—the elevatory movements continued,—other masses of the bed of the chalk-ocean, and of the Wealden strata beneath, became dry land,—and at length those more recent deposits containing the remains of the herbivorous mammalia which were the last tenants of the country. The oak, elm, ash, and other trees of modern Europe now sprang up where the groves of araucarias and tree-ferns once flourished,—the stag, boar, and horse ranged over the plains in which were entombed the bones of the colossal reptiles,—and finally *Man* appeared, and took possession of the soil.

At the present time, the deposits containing the remains

of the mammoth and other extinct mammalia are the sites of towns and villages, and support busy communities of the human race; the Huntsman courses, and the Shepherd tends his flocks, on the elevated masses of the bottom of the ancient chalk-ocean,*—the Farmer reaps his harvests upon the cultivated soil of the delta of the country of the Iguanodon,†—and the Architect obtains from beneath the petrified forest the materials with which to construct his temples and his palaces:‡ while from these various strata, the Geologist gathers together the relics of the beings that lived and died in periods of unfathomable antiquity, and endeavours by these natural memorials to determine the nature and succession of those physical revolutions which preceded all human history and tradition.

47. RETROSPECT.—Such is a plain enunciation of the results of our investigations; but I will embody these inductions in a more impressive form, by employing the metaphor of an Arabian writer, and imagining some higher intelligence from another sphere to describe the physical mutations of which he may be supposed to have taken cognizance, from the period when the forests of Portland were flourishing, to the present time.

"Countless ages ere man was created," he might say, "I visited these regions of the earth, and beheld a beautiful country of vast extent, diversified by hill and dale, with its rivulets, streams, and mighty rivers flowing through fertile plains. Groves of tall ferns and forests of coniferous trees clothed its surface; and I saw monsters of the reptile-tribe, so huge that nothing among the existing races can compare with them, basking on the banks of its rivers, and roaming through its forests; while in its marshes and lagoons thousands of crocodiles and turtles crept and swam. Winged

* The South Downs. † The Wealds of Kent and Sussex.
‡ The Isle of Portland.

reptiles of strange forms shared with birds the dominion of the insect-teeming air, and the waters abounded with fishes, shells, and crustacea.—And after the lapse of many ages I again visited the earth; the beautiful country, and its innumerable dragon-forms, its rivers, and its tropical forests, all had disappeared, and an ocean had usurped their place. And its waters teemed with nautili, ammonites, and other cuttle-fishes, of races now extinct, and with innumerable fishes and marine reptiles. — And thousands of centuries rolled by, and I returned, and, lo! the ocean was gone, and dry land had again appeared, and it was covered with groves and forests; but these were wholly different in character from those of the vanished country of the Iguanodon. And I beheld herds of deer of enormous size, quietly browsing, and groups of elephants, mastodons, and other herbivorous animals of colossal magnitude. And I saw in its rivers and marshes the hippopotamus, tapir, and rhinoceros; and I heard the roar of the lion and the tiger, and the yell of the hyena and the bear.—And another epoch passed away, and I came again to the scene of my former contemplations; and all the mighty forms which I had left had disappeared, the face of the country no longer presented the same aspect: it was broken into islands, and the bottom of the sea had become dry land, and what before was dry land had sunk beneath the waves. Herds of deer were still to be seen on the plains, with swine, and horses, and oxen; and bears and wolves in the woods and forests. And I beheld human beings, clad in the skins of animals, and armed with clubs and spears; and they had formed themselves habitations in caves, constructed huts for shelter, and enclosed pastures for cattle, and were endeavouring to cultivate the soil.—And a thousand years elapsed, and I revisited the country, and a village had been built upon the sea-shore, and its inhabitants supported themselves by fishing; and they had erected a temple on the neighbouring hill, and dedicated it

to their patron saint. And the adjacent country was studded with towns and villages; and the downs were covered with flocks, and the valleys with herds, and the corn-fields and pastures were in a high state of cultivation, denoting an industrious and peaceful community.—And lastly, after an interval of many centuries, I arrived once more, and the village was swept away, and its site covered by the waves; but in the valley and on the hills above the cliffs a beautiful city appeared; * with its palaces, its temples, and its thousand edifices, and its streets teeming with a busy population in the highest state of civilization; the resort of the nobles of the land, the residence of the monarch of a mighty empire." †

* Brighton.

† The concluding portion of these remarks refers to the changes that have taken place on the Sussex coast during the historical era. Before the Conquest, the greater part of the then little fishing-town of Brighthelmston (*Brighthelm's-town*), or Brighton, was situated below the cliffs, on a terrace of beach and sand, now covered by the waves. The church, dedicated to St. Nicholas, the patron-saint of fishermen, was placed on an eminence, that it might serve as a land-mark. The inroads of the sea led to the erection of buildings on the high ground, and its progressive encroachment gradually diminished the area of the ancient town, until at length a sudden inundation, but little more than a century ago, swept away the houses, fortifications, and enclosures that remained. The sea has, therefore, only resumed its former position at the base of the cliffs; the site of the old town having been an ancient bed of shingle, abandoned for ages by the ocean, perhaps, contemporaneously with the retreat of its waters from the valley of the Ouse. Should this re-advance of the sea be progressive, Lewes Levels (above, p. 61) may again become an estuary, and the town of the *Cliff* and the hamlet of *Landport* regain the characters from which their names were derived. See *A Day's Ramble in and about the ancient town of Lewes*: by the Author. 1846. Bohn.

APPENDIX.

SUPPLEMENTARY NOTES.

A. *Page* 41.—THE SURFACE OF THE MOON.—The moon is the only planetary body placed sufficiently near us to have the inequalities of its surface rendered distinctly visible with the telescope. Attendant on the earth, and having nearly the same density, we may reasonably infer that the mineral substances of which it is composed do not differ essentially from those on the surface of our own planet. If, as is most probable, the moon is surrounded by an atmosphere, it must be very clear and low, for it scarcely occasions a sensible refraction of the rays of light when it passes over the fixed stars. Many of the dark parts of the moon, particularly the part called *mare crisium*, appear to be covered with a fluid, which is probably more transparent than water, as the forms of the rocks and craters are seen beneath it, but not so distinctly as in the lighter parts of the moon's surface. To examine the moon with a reference to its external structure, the defining power of the telescope should be of the first quality, sufficient to show the projections of the outer illuminated limb, as distinctly as they appear when the moon is passing over the disk of the sun during a solar eclipse. With such a telescope, and a sufficient degree of light and of magnifying power, almost every part of the moon's surface appears to be volcanic, containing craters of enormous magnitude and vast depth: the shelving rocks and the different internal ridges within them seem to mark the stations at which the lava has stood and formed a floor during different eruptions; while the cones in some of the craters resemble those formed within modern volcanos. The largest mountain on the southern limb of the moon, like the largest volcanic cone on the earth, Chimborazo,

has no deep crater on its summit. There are indeed the outlines of the crater, but it is nearly filled up; while from the foot of this lunar mountain streams of lava diverge in different directions, to the distance of six hundred miles. The longest known current of modern lava on the earth is in Iceland, and extends sixty miles; but the volcanos in that island bear no proportion to those of the moon in magnitude.—*Mr. Bakewell.*

B. *Page* 42.—Nebular Theory of the Universe.—The following remarks by one of the most eminent philosophers of our times are appended with the view of showing that, although the nebular theory cannot be regarded as having any pretensions to be considered as a philosophical theory supported by direct observations, yet, as suggestive of the effects of a law by which it seems probable the sidereal universe is governed, it is deserving the highest consideration:—"Should the powers of an instrument, such as Lord Rosse's telescope, succeed in demonstrating the starry nature of the regular elliptic nebulæ which have hitherto resisted such decomposition, the idea of a *nebulous matter*, in the nature of a shining fluid or condensible gas, must, of course, cease to rest on any support derived from actual observations in the sidereal heavens, whatever countenance it may still receive in the minds of cosmogonists from the tails and atmospheres of comets, and the zodiacal light in our own system. But, though all idea of its ever being given to mortal eye to view aught that can be regarded as an outstanding portion of primeval chaos be dissipated, it will by no means have been even then demonstrated that among those stars so confusedly scattered no aggregating powers are in action, tending to draw them into groups, and insulate them from neighbouring clusters; and, speaking from my own impression, I should say, that in the structure of the Magellanic Clouds it is really difficult not to believe we see distinct evidences of the exercise of such a power. Much has been said of late of the nebulous hypothesis as a mode of representing the origin of our own planetary system.—An idea of Laplace, of which it is impossible to deny the ingenuity, of the successive abandonment of planetary rings, collecting themselves into planets by a revolving mass gra-

dually shrinking in dimensions by the loss of heat, and finally concentrating itself into a sun, has been insisted on with some pertinacity, and supposed to receive almost demonstrative support from considerations to which I shall presently refer. I am by no means disposed to quarrel with the nebulous hypothesis even in this form, as a matter of pure speculation, and without any reference to final causes; but, if it is to be regarded as a demonstrated truth, or as receiving the smallest support from any observed numerical relations which actually hold good among the elements of the planetary orbits, I beg leave to demur. If we go on to push its application to that extent, we clearly theorize in advance of all inductive observation." —*Address to the British Association held at Cambridge, in June*, 1845; *by Sir J. F. W. Herschel, Bart.*

C. *Page* 76.—THE LAKE OF THE SOLFATARA.—"Its temperature was in the winter in the warmest parts above 80 deg. of Fahrenheit, and it appears to be pretty constant; for I have found it differ a few degrees only, in January, March, May, and the beginning of June: it is therefore supplied with heat from a subterraneous source, being nearly twenty degrees above the mean temperature of the atmosphere. Kircher has detailed in his *Mundus Subterraneus* various wonders respecting this lake, most of which are unfounded; such as that it is unfathomable, that it has at the bottom the heat of boiling water, and that floating islands rise from the gulf which emits it. It must certainly be very difficult, or even impossible, to fathom a source, which rises with so much violence from a subterraneous excavation; and at a time when chemistry had made small progress, it was easy to mistake the disengagement of carbonic acid for an actual ebullition. The floating islands are real, but neither the Jesuit, nor any of the writers who have since described this lake, have had a correct idea of their origin, which is exceedingly curious. The high temperature of this water and the quantity of carbonic acid that it contains render it peculiarly fitted to afford a pabulum or nourishment to vegetable life; the banks of travertine are everywhere covered with reeds, lichens, confervæ, and various kinds of aquatic vegetables; and at the same time that the process of vegetable life

is going on, the crystallizations of the calcareous matter which is everywhere deposited, in consequence of the escape of carbonic acid, likewise proceed, giving a constant milkiness to what from its tint would otherwise be a blue fluid. So rapid is the vegetation, owing to the decomposition of the carbonic acid, that, even in winter, masses of confervæ and lichens, mixed with deposited travertine, are constantly detached by the currents of water from the bank, and float down the stream, which, being a considerable river, is never without many of these small islands on its surface: they are sometimes only a few inches in size, and composed merely of dark-green confervæ, or purple or yellow lichens; but they are sometimes even of some feet in diameter, and contain seeds and various species of common water-plants, which are usually more or less incrusted with marble. There is, I believe, no place in the world where there is a more striking example of the opposition or contrast of the laws of animate and inanimate nature,—of the forces of inorganic chemical affinity, and those of the powers of life. Vegetables, in such a temperature, and everywhere surrounded by food, are produced with a wonderful rapidity; but the crystallizations are formed with equal quickness, and they are no sooner produced than they are destroyed together. Notwithstanding the sulphurous exhalations from the lake, the quantity of vegetable matter generated there and its heat make it the resort of an infinite variety of insect tribes; and even in the coldest days in winter numbers of flies may be observed on the vegetables surrounding its banks, or on its floating islands, and a quantity of their larvæ may be seen there sometimes incrusted and entirely destroyed by calcareous matter; which is likewise often the fate of the insects themselves, as well as of various species of shell-fish that are found amongst the vegetables which grow and are destroyed in the travertine on its banks. Snipes, ducks, and other water-birds, often visit these lakes, probably attracted by the temperature and the quantity of food in which they abound; but they usually confine themselves to the banks, as the carbonic acid disengaged from the surface would be fatal to them if they ventured to swim upon it when tranquil. In May, 18—, I fixed a stick on a mass of travertine covered by the water, and I examined it in the beginning of the April following, for the purpose of determining the nature of the depositions. The water was lower at this time, yet I had some

difficulty, by means of a sharp-pointed hammer, in breaking the mass which adhered to the bottom of the stick; it was several inches in thickness. The upper part was a mixture of light tufa and the leaves of confervæ; below this was a darker and more compact travertine, containing black and decomposed masses of confervæ; in the inferior part, the travertine was more solid and of a grey colour, but with cavities which, I have no doubt, were produced by the decomposition of vegetable matter. I have passed many hours, I may say many days, in studying the phenomena of this wonderful lake; it has brought many trains of thought into my mind connected with the early changes of our globe; and I have sometimes reasoned from the forms of plants and animals preserved in marble in this warm source to the grander depositions in the secondary rocks, where the zoophytes or coral insects have worked upon a grand scale, and where palms and vegetables now unknown are preserved with the remains of crocodiles, turtles, and gigantic extinct saurians, which appear to have belonged to a period when the whole globe possessed a much higher temperature. I have likewise often been led, from the remarkable phenomena surrounding me in that spot, to compare the works of man with those of nature. The baths, erected there nearly twenty centuries ago, present only heaps of ruins, and even the bricks of which they were built, though hardened by fire, are crumbled into dust; whilst the masses of travertine around it, though formed by a variable source from the most perishable materials, have hardened by time; and the most perfect remains of the greatest ruins in the eternal city, such as the triumphal arches and the Colosseum, owe their duration to this source. . . . . .

How marvellous are those laws by which the humblest types of organic existence are preserved, though born amidst the sources of their destruction, and by which a species of immortality is given to generations floating, as it were, like evanescent bubbles, on a stream raised from the deepest caverns of the earth, and instantly losing what may be called its spirit in the atmosphere." — *Sir Humphry Davy's Consolations in Travel, or the Last Days of the Philosopher.*

D. *Page* 78.—Caverns.—One of the most common appearances in limestone-caverns is the formation of what are called *stalactites*,

from a Greek word signifying distillation or dropping. To explain these, a brief description of the mode of their production will be necessary. Whenever water filters through a limestone-rock, it dissolves a portion of it; and on reaching any opening, such as a cavern, oozes from the sides or roof, and forms a *drop*, the moisture of which is soon evaporated by the air, and a small circular *plate* or *ring* of calcareous matter remains; another drop succeeds in the same place, and adds, from the same cause, a fresh coat of incrustation. In time, these successive additions produce a long, irregular, conical projection from the roof, which is generally hollow, and is continually being increased by the fresh accession of water, loaded with calcareous or chalky matter; this is deposited on the outside of the *stalactite* already formed, and, trickling down, adds to its length by subsiding to the point, and evaporating as before; precisely in the same manner as, during frosty weather, icicles (which are *stalactites of ice or frozen water*) are formed on the edges of the eaves of a roof. When the supply of water holding lime in solution is too rapid to allow of its evaporation at the bottom of the *stalactite*, it drops to the floor of the cave, and, drying up gradually, forms, in like manner, a stalactite rising upwards from the ground, instead of hanging from the roof; this is called, for the sake of distinction, *stalagmite*.

It frequently happens, where these processes are uninterrupted, that a *stalactite*, hanging from the roof, and a *stalagmite*, formed immediately under it from the superabundant water, increase until they unite, and thus constitute a natural pillar, apparently supporting the roof of the grotto; it is to the grotesque forms assumed by stalactites, and these natural columns, that caverns owe the interesting appearances described in such glowing colours by those who witness them for the first time. One of the most beautiful stalactitic caverns in England is at Clapham, near Ingleborough. In the Cheddar Cliffs, Somersetshire, there has been discovered a similar cave, richly encrusted with sparry concretions. There are others in Derbyshire.

E. *Page* 78.—Weyer's Cave.—This cave is situated in a ridge of limestone-hills, running parallel to the Blue Mountains. A narrow and rugged fissure leads to a large cavern, where the most grotesque

figures, formed by the percolation of water through beds of limestone, present themselves, while the eye, glancing onward, watches the dim and distant glimmers of the lights of the guides—some in the recess below, and others in the galleries above. Passing from these recesses, the passage conducts to a flight of steps that leads into a large cavern of irregular form and of great beauty. Its dimensions are about thirty feet by fifty. Here the incrustations hang just like a sheet of water that has been frozen as it fell; there they rise into a beautiful stalactitic pillar; and yonder compose an elevated seat, surrounded by sparry pinnacles. Beyond this room is another, more irregular, but more beautiful; for, besides having sparry ornaments in common with the others, the roof overhead is of the most admirable and singular formation. It is entirely covered with *stalactites*, which are suspended from it like inverted pinnacles; and they are of the finest material, and most beautifully shaped and embossed. In another apartment, an immense sheet of transparent *stalactite*, which extends from the roof to the floor, emits, when struck, deep and mellow sounds, like those of a muffled drum. Farther on is another vaulted chamber, which is one hundred feet long, thirty-six wide, and twenty-six high. Its walls are filled with grotesque concretions. The effect of the lights placed by the guides at various elevations, and leaving hidden more than they reveal, is extremely fine. At the extremity of another range of apartments, a magnificent hall, two hundred and fifty feet long and thirty-three feet high, suddenly appears. Here is a splendid sheet of rock-work, running up the centre of the room, and giving it the aspect of two separate and noble galleries; this partition rises twenty feet above the floor, and leaves the fine span of the arched roof untouched. There is here a beautiful concretion, which has the form and drapery of a gigantic statue; and the whole place is filled with stalagmitical masses of the most varied and grotesque character. The fine perspective of this room, four times the length of an ordinary church, and the amazing vaulted roof spreading overhead, without any support of pillar or column, produce a most striking effect. In another apartment, which has an altitude of fifty feet, there is at one end an elevated recess, ornamented with a group of pendant stalactites of unusual size and singular beauty. They are as large as the pipes of a full-sized organ, and ranged with great regularity; when struck,

they emit mellow sounds of various keys, not unlike the tones of musical glasses. Other cavities, profusely studded with sparry incrustations, extend through the limestone-rock. The length of this extraordinary group of caverns is not less than one thousand six hundred feet.—*Abridged from "A Narrative of a Visit to the American Churches;" by Drs. Reed and Matheson. See also an interesting Narrative of "A Tour to the Caves in Virginia," by the late Dr. Harlan, Medical and Physical Researches*, p. 404.

F. *Page* 92.—Recent Formation of Sandstone.—"A sandstone occurs in various parts of the northern coast of Cornwall, which affords a most instructive example of a recent formation, since we here actually detect Nature at work in converting loose sand into solid rock. A very considerable portion of the northern coast of Cornwall is covered with calcareous sand, consisting of minute particles of comminuted shells, which, in some places, has accumulated in quantities so great, as to have formed hills of from forty to sixty feet in elevation. In digging into these sand-hills, or upon the occasional removal of some part of them by the winds, the remains of houses may be seen: and in places, where churchyards have been overwhelmed, a great number of human bones may be found. The sand is supposed to have been originally brought from the sea by hurricanes, probably at a remote period. At the present moment, the progress of its incursion is arrested by the growth of the *arundo arenacea*. The sand first appears in a slight but increasing state of aggregation on several parts of the shore in the Bay of St. Ives; but on approaching the Gwythian River it becomes more extensive and indurated. On the shore opposite Godrevy Island, an immense mass of it occurs, of more than a hundred feet in length, and from ten to twenty in depth, containing entire shells and fragments of clay-slate; it is singular that the whole mass assumes a striking appearance of stratification. In some places it appears that attempts have been made to separate it, probably for the purpose of building, for several old houses in Gwythian are built of it. The rocks in the vicinity of this recent formation in the Bay of St. Ives are greenstone and clay-slate, alternating with each other. The clay-slate is in a state of rapid

decomposition, in consequence of which large masses of the horn-blende-rock have fallen in various directions, and given a singular character of picturesque rudeness to the scene. This is remarkable in the rocks which constitute Godrevy Island. It is around the promontory of New Kaye that the most extensive formation of sandstone takes place. Here it may be seen in different stages of induration, from a state in which it is too friable to be detached from the rock upon which it reposes, to a hardness so considerable that it requires a very violent blow from a sledge to break it. Buildings are here constructed of it; the church of Cranstock is entirely built with it; and it is also employed for various articles of domestic and agricultural uses. The geologist who has previously examined the celebrated specimen from Guadaloupe will be struck with the great analogy which it bears to this formation. Suspecting that masses might be found containing human bones, if a diligent search were made in the vicinity of those cemeteries which have been overwhelmed, I made some investigations in those spots, but, I regret to add, without success. The rocks upon which the sandstone reposes are alternations of clay-slate and slaty limestone. The inclination of the beds is S.S.W., and at an angle of 40°. Upon a plane formed by the edges of these strata, lies a horizontal bed of rounded pebbles, cemented together by the sandstone which is deposited immediately above them, forming a bed of from ten to twelve feet in thickness, containing fragments of slate and entire shells, and exhibiting the same appearance of stratification as that noticed in St. Ives' Bay. Above this sandstone lie immense heaps of drifted sand. But it is on the western side of the promontory of New Kaye, in Fishel Bay, that the geologist will be most struck with this formation; for here no other rock is in sight. The cliffs, which are high and extend for several miles, are entirely composed of it; they are occasionally intersected by veins and dykes of breccia. In the cavities, calcareous stalactites of rude appearance, opaque, and of a grey colour, hang suspended. The beach is covered with disjointed fragments, which have been detached from the cliffs above, many of which weigh two or three tons."—*From a Memoir by Dr. Paris, in the Transactions of the Royal Geological Society of Cornwall.*

G. *Page* 109.—On the Subsidence of the Coast at Puzzuoli. *Letter from C. Hullmandel, Esq., to the Author, "London, November,* 1839.—"Most travellers merely pass through Puzzuoli in their way to Baia, and, few being acquainted with the Neapolitan dialect, many have not had the opportunities which I enjoyed of conversing with the natives upon the subject. In the year 1813, I resided for four months in the Capuchin convent of Puzzuoli, which is situated between the road from Naples and the sea, at the entrance of the town of Puzzuoli. In the Capuchin convents the oldest friar is called '*il molto reverende;*' and the one who then enjoyed the title in this convent was 93 years old. He informed me that, when he was a young man, the road from Naples passed on the *seaward side* of the convent; but that, from the gradual sinking of the soil, the road was obliged to be altered to its present course.

"While I was staying at the convent, the refectory, as well as the entrance gate, were from six inches to a foot under water whenever strong westerly winds prevailed so as to cause the waters of the Mediterranean to rise. Thirty years previously, my old informant stated, such an occurrence never took place. In fact, it is not probable that the builder of the convent would have placed the ground-floor so low as to expose it to inundation, as it now is. Moreover, the small wharf at Puzzuoli, like the convent, is constantly under water when westerly winds prevail; here again it is evident that the original constructors of the wharf never intended it to be in this state. These facts appear to prove that the gradual subsidence of the soil has been going on for many years, and is still in actual progress, and corroborate the opinion derived from the appearances observable on the columns of the Temple of Jupiter Serapis, that the country has been subjected to alternate elevations and subsidences."

DESCRIPTION OF THE PLATES

OF

VOLUME I.

DESCRIPTION OF THE FRONTISPIECE.

(*See page* 453.)

A PICTORIAL ILLUSTRATION OF THE COUNTRY OF THE IGUANODON; FOUNDED ON THE GEOLOGICAL DISCOVERIES OF THE AUTHOR.

BY JOHN MARTIN, ESQ., K.L.

THE mode of induction by which the geologist and comparative anatomist are enabled to ascertain the form and structure of animals and plants which no longer exist on the face of the earth, and even the nature of the countries which they inhabited, is explained in the preceding pages. From the materials furnished by the researches of the Author in the Wealden formation of the south-east of England, the eminent painter of "BELSHAZZAR'S FEAST" (Mr. John Martin) composed the striking picture that forms the frontispiece of this Work.

The data upon which the restorations are founded are described in the Fourth Lecture, Part II. (see p. 370). The painting represents a country clothed with a tropical vegetation, peopled by colossal reptiles, and traversed by a river, which is seen to empty itself into the sea in the distance. Oolitic rocks form the heights and cliffs with which the landscape is diversified. The vegetation consists of the trees and plants whose fossil remains have been discovered in Tilgate Forest in the Isle of Wight, and at Portland, namely, arborescent ferns, zamias, and coniferous trees; the lesser species being distributed over the foreground.

The greater reptiles are the Iguanodon (p. 436), Hylæosaurus (p. 449), Megalosaurus (p. 435), and Crocodiles (p. 428). An Iguanodon attacked by a Megalosaurus and Crocodile constitute the principal group; in the middle distance an Iguanodon and Hylæosaurus are preparing for an encounter; a solitary Pterodactyle, or flying reptile (452), with its wings partly expanded, forms a conspicuous object in the foreground; while Tortoises are seen crawling on the banks of the river. Ammonites and other shells of the Portland Oolite, which is the foundation-rock of the country, are strewn on the shore.

DESCRIPTION OF THE GEOLOGICAL MAP OF ENGLAND.

PLATE I.

THIS map, or rather ground-plan, is necessarily on too small a scale to afford more than a very general idea of the geographical distribution of the principal groups of strata over England, in accordance with the chronological synopsis in Lecture III.

A summary of the general features of the country is given in page 207, which it is unnecessary here to repeat; but it may be interesting to offer a slight sketch of the Geology of the shores of England. With this view, if we start on an imaginary cruise from the north, beyond Berwick, and proceed along the eastern, south-eastern, and southern coasts, to the Land's-End, and then sail along the western shores until we reach the Solway Firth, the following geological phenomena will successively be presented.

The border-country of England and Scotland consists of *Mountain-limestone*, with a narrow track of *Devonian* north of Berwick, in which fossil fishes have been met with, and beyond which, still further to the north, are slaty rocks of *Silurian* age. From Berwick to Shields, *Carboniferous* rocks, comprising the *Mountain-limestone*, *Coal*, and *Millstone-grit*, form the Northumberland coast; a few insulated masses of Plutonic rocks (*Trap*) appear here and there; as for example, at Bamborough Castle and Dunstanborough. From near Tynemouth to Hartlepool, the *Magnesian limestones* of the *Permian* system appear; thence to Redcar, the *Trias* deposits, in which the embouchure of the river Tees is situated, form the shore.

The coast of the North Riding of Yorkshire, composed of *Lias* and *Oolite*, is now reached; this tract includes Whitby, in the neighbourhood of which place are high cliffs of Lias, abounding in fossils of great variety and interest, as for example, Ichthyosauri and other reptiles, jet, wood, and numerous shells. In the continuance of this coast to Scarborough and Speeton, the *Great Oolite*, *Coral-rag*, *Oxford Clay*, and other members of the Oolite appear, containing organic remains in profusion; and along this shore are exposed intercalated *fluvio-marine* strata, full of cycadeous plants, ferns, equisetites, lignite, and coal. Thence to Flamborough Head, the *Lower Greensand* (very thin), *Speeton Clay*, and *Red Chalk* emerge, and finally the *White Chalk*, of which the high cliffs of the promontory consist. From

GEOLOGICAL MAP OF ENGLAND

E. Weller. Sculp.

the rivers from the interior discharge their waters into the sea, now stretches along the coast towards Brighton; where, to the extent of three or four miles, the cliffs consist of detritus, containing bones of elephants, whales, horses, deer, and other mammalia. At the embouchure of the river Ouse, which flows into the sea from Lewes, the chalk-cliffs forming the western headland of Newhaven harbour are capped by Eocene strata.

To the west of Brighton, the coast is for the most part low; the foundation-rock of the district, Chalk, seldom rising into view; and thick beds of gravel and brick-earth, with Eocene strata beneath, form the tract on the south of the Downs, through western Sussex and the adjacent maritime district of Hampshire.

The Sussex coast at Bognor is skirted by a few low rocks of calciferous sandstone, abounding in eocene shells identical with those of the London Clay: and in Bracklesham bay a bank of clay and sand, usually covered by the tide, has yielded numerous organic remains of great interest.

We now sail round the eastern termination of the Isle of Wight, and perceive on the north the Tertiary strata in Whitecliff Bay, abutting against the vertical Chalk of Culver Cliff. Rounding the promontory, we enter Sandown Bay, where the Wealden beds rise in an anticlinal position from under the Cretaceous strata. The ruinous chalk-escarpment of the Undercliff is next passed, and we enter another bay of the Wealden, at Brixton, Brook, and Compton; and again meet with bold precipices of Chalk at Freshwater Gate and the Needles; and vertical Eocene strata in Alum Bay.

Pursuing our westward course, we see the distant coast of Hampshire, by Hordwell and Christchurch, formed of freshwater and marine Tertiary deposits; and entering Studland Bay, perceive Tertiary sands flanking the northern side of the vertical chalk-cliffs of Handfast Point. Swanage Bay, on the south side of the Point, exhibits a fine section of the Wealden strata; and Durlstone Bay, still further south, continues the section through the Purbeck beds. Coasting along the Isle of Purbeck, the different members of the Cretaceous and Wealden formations are seen in various parts of this sinuous and indented line of coast; in some places forming the entire cliffs; in others surmounting the Kimmeridge Clay and Portland Oolite; and we pass by the little coves in the south-west of the island, in which the strata of the Chalk, Wealden, and Oolite appear in a vertical position.

Rounding the insulated mass of *Oolite* that forms the Isle of Portland, we reach the Dorsetshire coast, which is here composed of beds of the *Inferior Oolite*. These deposits are succeeded near Lyme Regis by cliffs of *Lias*, which the researches of the late Miss Mary Anning and Mr. Hawkins have rendered so celebrated; the remains of Ichthyosauri, Plesiosauri, and other reptiles occur here in abundance and good preservation, together with numerous shells, crinoidea, crustacea, and plants.

The Lias is here capped with Greensand, and on the west succeeded by red marls of the Triassic series; and these, after a short interruption of Greensand and Chalk, reappear and continue by Sidmouth, Exmouth, and Teignmouth to near Babbicombe, where the *Devonian* or *Old Red deposits* first emerge: beautiful coralline marbles are quarried near Babbicombe.

The coasts of Devonshire and Cornwall, with but few interruptions, are made up of the different members of the Devonian system; *Silurian* strata occurring at a few points. *Mica* and *Chlorite schists* form the promontory at Start Point; *Serpentine* and *Diallage rock*, the Lizard; and *Granite*, the Land's-End. From Plymouth to Falmouth is the grand region of copper-ores; the country consisting of slaty rocks (termed *Killas*) traversed by dikes both of coarse and of fine grained granites (provincially called *Elvans*), and broken through by protrusions of granitic rocks. Intrusions of *Trap* are frequent all over this part of England; at St. Ives, the cliffs are composed of this igneous product.

The western shores of Cornwall present similar phenomena; and throughout this sea-coast, elevated terraces of beach or shingle are numerous, proving the frequent alterations in the relative level of sea and land, which have here taken place.

Along the west coast of Devonshire, beds of the *Carboniferous* system appear; the shales are often highly contorted, and occur in the state of indurated slate, provincially called *Culm*: they contain shells and many of the usual species of coal-plants.

In north Devonshire, the Devonian system reappears; and near Ilfracombe there are beds of limestone and calcareous slates, full of shells and corals. If we pass up the Bristol Channel, as far as Watchet, we find cliffs of Lias, abounding in shells and reptilian remains.

But it would extend this notice to too great a length, were I to point out every interesting locality within view, in our voyage along the western coasts of England: it must, therefore, suffice to mention only the most striking geological phenomena.

Crossing to the opposite Welsh coast, Mountain-limestone, capped by Lias, appears at Nash Point, and near Dunraven; and in Swansea and Caermarthen Bays, we perceive the great South-Welsh Coal-measures fully developed; the promontory of Worm's Head, which lies between the bays, is composed of Devonian strata and Mountain-limestone. Near Tenby, the cliffs are formed of Carboniferous deposits, very much contorted; and beyond, at St. Goven's Head, beds of Mountain-limestone appear under similar conditions. In Milford Haven, which is chiefly flanked by Devonian rocks, Silurian deposits appear near St. Ann's Head; and there are numerous isolated masses of Trap: Ramsey Island and St. David's Head also consist of these igneous rocks traversing Silurian strata.

We now enter Cardigan Bay, which is cut out of the Lower Silurian and Cambrian deposits. The strata consist for the most part of slates with characteristic fossils, which are associated with contemporaneous and intrusive igneous rocks. Mica and chlorite schists form the cliffs on the southern headland of Caernarvon Bay, and similar rocks occur in the Menai Straits, and at Holyhead, with interspersions of Devonian, Silurian, and Carboniferous strata. Along the coast of Denbighshire, the Upper Silurian strata reach the coast, and are succeeded by Carboniferous and Triassic deposits.

Crossing the embouchure of the river Dee, which is situated in the Coal-measures, the Triassic sandstones of Cheshire appear at Birkenhead. Marine detritus and alluvium obscure the regular strata along this part of the Lancashire coast, until beyond Lancaster Bay, where Upper and Lower Silurian strata and Mountain-limestone appear, succeeded by a low coast with Triassic beds.

At St. Bees Head, the coast exhibits Coal-measures, covered by *Permian* deposits; and at Whitehaven and Workington, the sea-shores are entirely composed of Carboniferous strata, the beds of coal being worked far under the sea. At Maryport, the Magnesian limestone of the Permian system forms the cliffs. We now enter the Solway Firth, and terminate this rapid sketch of the geological phenomena exhibited by the coasts of England.

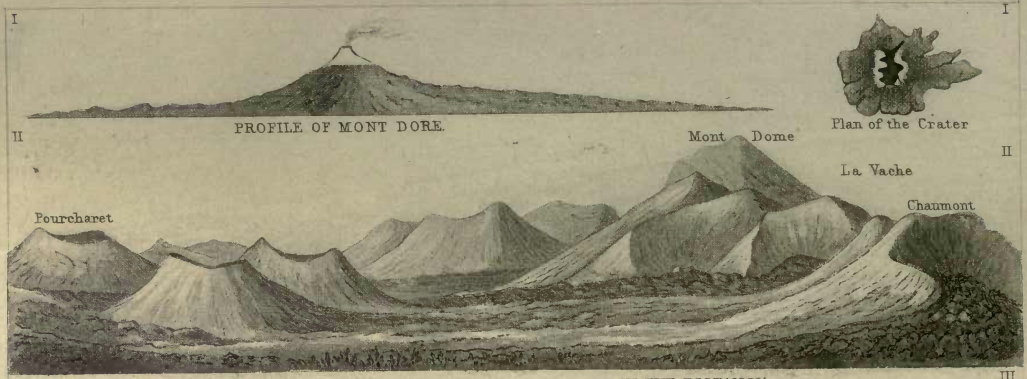
DESCRIPTION OF PLATE II.

EXTINCT VOLCANOS OF AUVERGNE.

I. Profile of Mont Dore, as seen from a distance; with a plan of the crater of the mountain: see page 275.

II. Part of the southern chain of Puys; exhibiting the broken craters of Chaumont, each with a current of lava issuing from its base: Mont Dome is seen in the distance: see page 273.

III. View of the Environs of Clermont, from the Puy Girou.



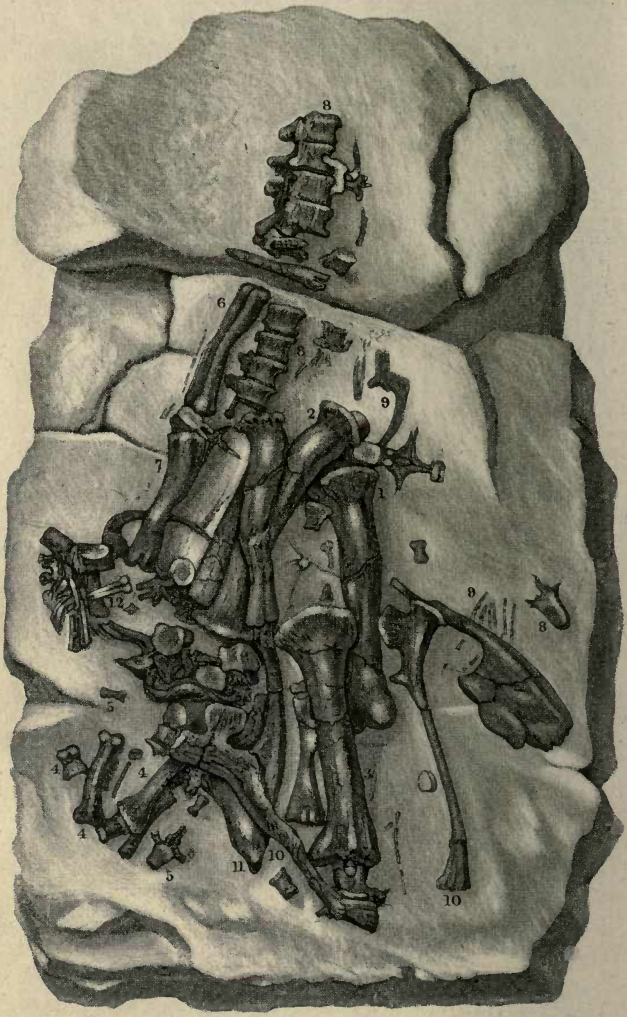
PROFILE OF MONT DORE.

Plan of the Crater

VIEW OF THE CHAIN OF PUYS. MONT DOME IN THE DISTANCE

VIEW OF THE ENVIRONS OF CLERMONT, FROM THE PUY GIROU.

E.Weller Sculp.



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PART OF THE SKELETON OF AN IGUANODON
FROM A QUARRY NEAR MAIDSTONE.
(Length of the Specimen eight feet.)

In the foreground is a basaltic peak, on the summit of which is the Castle of Montrognon. The town of Clermont is seen in the valley immediately beyond; and Montferrand in the plain on the right.

The dark horizontal lines indicate the basaltic platform which caps the summits of the hills of fresh-water limestone. These beds of basalt are between 300 and 400 feet in thickness, and are spread over limestone strata, which, together with the basalt, were once continuous, but have since been eroded; the detritus having been carried away by alluvial action: see page 277.

In the remote distance is the granitic escarpment forming part of the boundary of the plain of Auvergne; see page 270.

[These views are reduced from the Plates of Mr. Poulett Scrope's valuable and elegant work on the Extinct Volcanos of Central France.]

DESCRIPTION OF PLATE III.

THE REMAINS OF AN IGUANODON; FROM THE KENTISH RAG, NEAR MAIDSTONE.

Described pp. 442–444.

(Length of the original eight feet).

1, 2. The right and left thigh-bones, or *femora*.
3. A leg-bone, or *tibia*.
4, 4, 4. Bones of the toes (*metatarsal* and *phalangeal*) of the hind feet.
5. (The upper fig. 5.) *Ungual*, or claw-bone.
6. Two *metacarpals*, or first finger-bones of the fore-foot (?): [*Ulna* and *radius*, according to Prof. Owen.]
7. Bone of the arm (*humerus*).
8, 8, and the lower fig. 5. Vertebræ of the back and tail: in the upper part of the specimen eight vertebræ remain in a consecutive series.
9, 9. Ribs; some nearly entire, others broken.
10, 10. Two clavicles, or collar-bones.
11. One of the bones of the pelvis (*iliac bone*). The fellow bone is near fig. 9.
12. A *chevron-bone*, or hæmal arch and spine of a vertebra.

DESCRIPTION OF PLATE IV.

REMAINS OF THE HYLÆOSAURUS, DISCOVERED IN TILGATE FOREST.

Described pp. 449—451.

(The original is four and a half feet in length.)

This plate represents the highly interesting specimen discovered in Tilgate Forest in the summer of 1832; it consists of the anterior portion of a skeleton of the *Hylæosaurus*, or Fossil Lizard of the Weald, lying on the back.

1. Portion of the base of the *cranium*.
2. Vertebræ of the neck, or *cervical*.
3. Vertebræ of the back, or *dorsal*.
4. Ribs, for the most part perfect, and but little removed from their articulations with the vertebræ.

5, 5, 5. Dermal spines.

6, 6, 6. Three very large dermal spinous processes: each 15 inches in length.

7, 7. Two *coracoid* bones (belonging to the chest).

8, 8. The two *scapulæ*.

9. The glenoid cavity, or socket for the head of the arm-bone, formed by the union of the coracoid and scapula.

10. Detached bones.

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(Length of the Specimen 4½ Inches.)

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